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SPECTRUM

MARCH 1995
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IN SENSOR RANGE

Mixing spectral bands for special purposes

newslog

JAN 9. NEC Corp., Tokyo, said it would produce IBM-compatible PCs for China with Shanghai-based **Changiang Computer Union Corp**. The joint venture would make NEC the first Japanese company to manufacture PCs in China.

JAN 10. British Telecommunications and **Viag**, one of Germany's biggest industrial groups, announced plans to form a $980 million joint venture to break into the German telecommunications market.

JAN 11. The **Justice Department** said it had formally notified **Airtouch Communications**, San Francisco, that as a former unit of the Pacific Telesis Group, it was still subject to the antitrust decree that broke up the Bell System in 1984. But the department said that Airtouch could continue to bundle cellular and long-distance phone services in a package until the issue is decided by district judge Harold H. Greene, who oversees the Bell decree.

JAN 11. Intel Corp. , Santa Clara, Calif., and **Advanced Micro Devices Inc.**, Sunnyvale, Calif., announced they had ended their seven-year legal battle over whether Advanced Micro had the right to make copies of Intel's microprocessor chip.The settlement calls for AMD to pay Intel US $58 million for past damages and Intel to pay AMD $18 million for breach of contract.

JAN 12. The **Federal Communications Commission** announced it had allocated a portion of the airwaves to digital audio radio, a new class of service that would bounce compact-disk–quality programming off satellites directly to listeners' radios. The National Association of Broadcasters said it would try to block the service.

JAN 13. Sandia National Laboratories, Albuquerque, N.M., said that by hooking up two of **Intel Corp.'s** Paragon supercomputers to each other, researchers had nearly doubled the world record in computing speed, clocking in at 281 gigaflops and leapfrogging Fujitsu Ltd.'s 170.4 gigaflops. Linked, the two Intel machines had 6786 processors working in parallel.

JAN 16. GTE Corp., Stanford, Conn., said a Federal court had ruled that the company might re-enter television services it had to abandon in the early '80s when cable TV laws went into effect. The decision gives GTE Telephone Operations the right to provide video programming to GTE local phone customers, some 17 million nationwide.

JAN 17. A Federal appeals court ordered district judge **Judge David N. Edelstein**, who has overseen the Justice Department's antitrust settlement with **IBM Corp.** for almost 40 years, to remove himself from the case, saying he does not appear impartial. IBM has repeatedly asked the judge, without success, to lift a 1956 consent degree that restricted the company's operations, saying the settlement was obsolete.

JAN 19. The **Electronic Industries Association of Japan** said that most semiconductor production in the Kobe region continued to operate normally after the **Jan. 17 earthquake**, but that officials were still checking liquid-crystal display production equipment at Toshiba and Sharp facilities, while Hosiden's Kobe factory had shut down its operations.

JAN 24. Japan's **Matsushita Electric Industrial Co.** said that it had endorsed the digital videodisk system developed by **Toshiba Corp.** because its images were of higher quality than those of the rival system developed by Sony Corp. and Philips Electronics NV.

JAN 24. CERN, the European Laboratory for Particle Physics near Geneva, Switzerland, said it was handing over its development of the World Wide Web to **Inria**, France's national computing research institute. Inria will work with the World Wide Web Consortium at the Massachusetts Institute of Technology in Cambridge.

JAN 24. The U.S. **Food and Drug Administration** and **Telectronics Pacing Systems**, Englewood, Colo., said they had advised 42 000 patients with certain pacemakers to be X-rayed for possibly fractured wires. Models 330-801 and 329-701 have been linked to two deaths and several injuries; model 330-812 was distributed outside the United States.

JAN 24. Inmarsat, the London-based satellite communications organization, said it had raised $1.4 billion from 38 telephone companies around the world to launch a global satellite system for hand-held phones by 1999.

JAN 25. Nynex Corp. said it had opened its New York market to local telephone competition by slashing what it charges rival **MFS Communications Corp.**, Omaha, Neb., for using its network, and had agreed to allow Nynex customers who switch to MFS to keep their phone numbers without charging them extra. The groundbreaking pact may be copied by other regional Bell companies.

JAN 26. Germany's **Veba AG** announced it would take a 10 percent stake in **Cable & Wireless PLC**, London. The partners are to create two joint ventures: one to focus on the German telecom market and one to obtain local partners in European markets.

JAN 26. China Great Wall Industrial Corp. said a Chinese Long March rocket carrying the U.S.-made Apstar 2 telecommunications satellite exploded over its launch pad in Sichuan province. Falling debris killed six people and injured 23. Apstar 2, built by **Hughes Space and Communications Co.**, Los Angeles, was to have provided TV and telecom links across Asia, Europe, and Africa.

JAN 30. Nippon Telegraph and Telephone Corp. said it would invest $123 million in **Smart Communications Inc.**, Manila, one of seven new common carriers in the Philippines. The deal will allow Smart to supply local phone service in the country's northern part.

JAN 31. AT&T Corp. and **VLSI Technology Inc.**, San Jose, Calif., said they would produce low-cost encoding chips more rugged than the Clipper chip proposed by the Clinton administration to ensure the privacy of voice and data communications. AT&T is providing the security software—a triple-strength version of the data encryption standard—while VLSI will produce the chips.

FEB 2. NASA said the **U.S. space shuttle Discovery** had rendezvoused with the **Russian space station Mir,** getting as close as 12 meters. The mission was a test flight for at least seven dockings of the U.S. space shuttle Atlantis and Mir through 1997.

Preview

MAR 28–31. The **Fifth Conference on Computers, Freedom, and Privacy** is to take place in Burlingame, Calif. Subjects to be spotlit will include the responsibility of electronic speech and copyright protection. For more information, call 415-548-9673.

SALLY CAHUR

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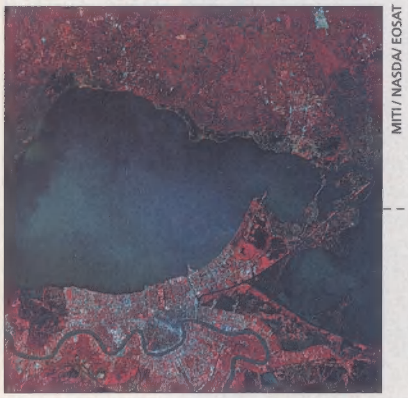

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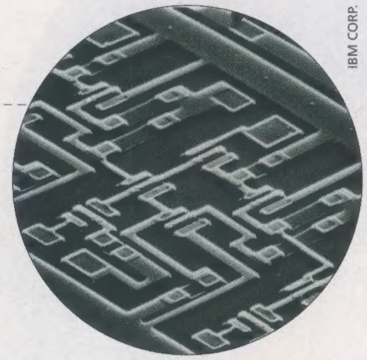

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forum

Bugged by software

The furor about the Pentium chip bug triggered in me an eruption of anger—a long-smoldering anger toward commercial software vendors.

Why does the public not exhibit the same response to software vendors that release expensive applications with bugs at least as bad as the Pentium bug? I understand that zero-defect software is probably not achievable in our lifetime, but I really get steamed when a software vendor either tries to explain why a bug is not really a bug or says that it will be fixed in the next release (available for only $99, by the way, and no promises). There are some vendors that will go out of their way to help with problems, while others take the attitude that, "Yes, it does seem to do that....Isn't that interesting."

Some of the bugs I have encountered from name brand vendors are so obvious that I do not see how the software could have gotten through beta testing. I could go on with numerous examples, but I hope I am not the only soul out here who would like to demand more from software vendors.

Bill Waggener
73240.1410@compuserve.com

Alarming monitors

As an M.D. anesthesiologist with an EE background, I often give thought to the design of the instrumentation on which the lives of my patients depend. For example, when I put a patient to sleep for heart surgery, I insert invasive and noninvasive monitoring lines to keep an eye on cardiac filling pressures, cardiac output pressures, and other parameters such as the electrical pacing and conduction properties of the heart.

Usually five or more signals and derived parameters (such as heart rate or mean blood pressure) are displayed in real time on a high-resolution monitor. These data are just as important to me as flight-related data are to an aircraft pilot, and form the basis for deciding, say, which drugs I administer to get out of clinical crises.

For instance, low blood pressure may be due to low cardiac output (flow) through normal-resistance blood vessels, or normal flow through low-resistance vessels. Determining which situation exists (and thus what drugs to give) when a patient's blood pressure is dangerously low obviously requires easy-to-use and reliable instrumentation.

Regrettably, experience with a number of monitor designs has taught me that much needs to be done to make operating room monitors trustworthy and ergonomically sensible. Some examples of monitoring problems, from my own or my clinical associates' experience, illustrate the point.

I know of two monitor designs that occasionally reboot for no apparent reason in the middle of surgery (possibly due to EMI from the electrosurgical apparatus, or even nearby cellular phones, but possibly also software-related). During the reboot, the patient is at increased risk. The situation is especially frustrating when the pressure-signal–related zero offset information is lost on reboot and the pressure transducers must all be rezeroed.

One monitor I know of on occasion slips into demo mode, displaying totally synthetic data, with a note to that effect in the corner of the display. When this happened to one clinician while transporting a patient, he was unable to quit the demo mode because he did not know the required service password!

The monitoring system I use most frequently will often announce an "asystole" (cardiac arrest) alarm when the electrocardiogram signal falls below a certain amplitude. The fact that normal cardiac pressures are still being generated is ignored by the alarm management software, resulting in an obviously wrong diagnosis.

This kind of haphazard and ill-conceived alarm arrangement is why many of my colleagues globally disable alarms at the start of surgery, so they can concentrate on taking care of the patient rather than follow up countless false alarms.

While my EE background is decidedly helpful to me in dealing with such instrumentation crises in the operating room, there is a clear need for better-designed instrumentation. I invite designers of patient monitors to spend some time in the operating room to appreciate how much needs to be done. At the very least, they should be interviewing users to understand the many problems with existing monitoring systems.

D. John Doyle
Toronto

Engineers Without Borders

In response to Scott Bugno's inquiry about volunteer organizations of engineers [October 1994, p. 4], here is some information about Ingeniería Sin Fronteras (ISF).

Our members are engineers, engineering students, and others who work in technical areas. In working for a juster world, we offer our knowledge, experience, and free time to less favored communities.

ISF is a nonpolitical organization. In Spain, it is five years old and has groups in more than 10 cities, always based on a university. There is a similar organization in France.

Our principal objectives are development projects, which are nonviolent and respectful of nature and of human rights; and programs to sensitize society through meetings, publications, and social movements.

For more information about ISF, the contacts in Europe are Marta Viudez, External Relationships, ISF - Pais Vasco, jtaviblm@s835cc.bi.ehu.es; in Madrid, isf@etsit.upm.es; in France, isf@ensta.fr.

Marta Viudez
jtaviblm@s835cc.bi.ehu.es

Magnetic fields: malign or maligned?

The article "Today's view of magnetic fields" by Tekla S. Perry [December 1994, pp. 14–23] was a well-balanced presentation on the possible hazards. I expect, though, that the self-appointed debunkers among us will say that there is no problem, or that we cannot know if there is one without taking several decades and billions of dollars to study the situation. Some of the debunkers sound very like the executives for the cigarette industry. I hope that we can take a more reasoned approach.

There is another option besides reducing the fields or waiting for more data. That is to increase the power frequency from 60 Hz to some higher value—say, in the range of 120 to 600 Hz. In this day of power electronics, this is not as far-fetched as at first seems.

It would have been nice to mention two books: *Body Electric: Electromagnetism and the Foundation of Life,* by Robert O. Becker and Gary Selden (Morrow, New York, 1987), and *Cross-Currents: The Perils of Electropollution, the Promise of Electromedicine,* by Robert O. Becker (J. P. Tarcher, Los Angeles, 1990). Becker has had a long career as a research orthopedic surgeon and has learned a lot about electrical engineering. Reading his books certainly changed my paradigm.

The issue of behavioral changes needs more attention. It is possible that societal instances of poor judgment are at least partly due to the influence of magnetic fields. Dr. Becker explores some of these issues.

Gary L. Johnson
Manhattan, Kan.

forum

Continued from p. 6

I am shocked and embarrassed by the foolishness found in the article. Readers interested in this important subject are strongly advised to read the article "Fields of Fear" by Gary Taubes in the November 1994 issue of *The Atlantic.* There they will find a balanced and reasonable discussion of the gross inadequacies of epidemiological studies performed to date, the fear-mongering that has emerged from them, and the scarce financial resources being squandered on them.

Thomas B. Jones
Rochester, N.Y.

The following is excerpted from a letter to the editor of The Atlantic *with permission from the writer, Louis Slesin, editor and publisher of* Micro Wave News.*—Ed.*

When lecturing researchers and reporters on how to do their own work ("Fields of Fear"), Taubes should get his own facts right. That's hard to do when he avoids talking to many of the people he cites and quotes, preferring instead to cull quotations that suit his agenda.

In my case, Taubes just made it all up. For the record, I would never have said that the "bulk of EMF research is paid for by the military" because for most of the last decade the military has hardly funded any studies at all.

Allow me one of many possible examples of Taubes's selective reporting: his dismissal of an association between EMFs and breast cancer. Taubes makes it sound as if the only reason for the growing suspicion that EMFs may promote breast cancer is a report from the Johns Hopkins University (JHU) School of Hygiene and Public Health of two cases among male workers, which was later "played...up widely" by the press.

Let's look at the facts: The JHU group announced the findings in November 1989 at a Department of Energy Conference as part of a larger set of results showing an association between EMF work and many different types of cancer, particularly leukemia. These findings might have passed unnoticed because no reporter attended the conference other than me.

The JHU researchers did not rush into print. They did not publish their results until March 1991—16 months later—and only after two other groups, one in the United States and one in Norway, published similar findings.

In addition, the JHU researchers identified six cases of male breast cancer, not two as Taubes reported. The other four cases occurred outside the study period and so were excluded from the statistical analysis, but this unexpectedly large cluster of cases of such a rare disease piqued their interest.

At this writing, five research teams have reported an association between male breast cancer and EMFs. And two of these groups later reported a *female* breast cancer-EMF link. Not every epidemiological study has found this link, but the human studies are supported by a series of impressive animal and cellular experiments, as well as mechanistic studies.

Is there a mislabeled graph on p. 21 of "Today's view of magnetic fields"? Is a typical room at home really 30 ft by 40 ft?

Doug S. Phillips
Calgary, Canada

It is if you want to have spots in the room not affected by fields.—Ed.

(Additional letters written in response to Spectrum's *article on EMF will be published in the coming issue.* *—Ed.)*

Corrections

On the second line of the second column in the Viewpoint on p. 32 of the January issue, the T1 speed ought to have been 1.544 Mb/s.

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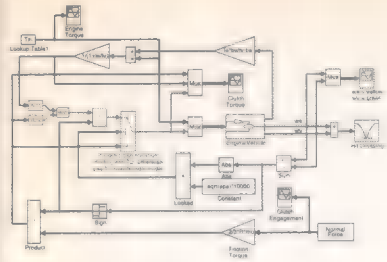

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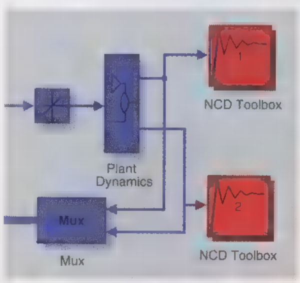

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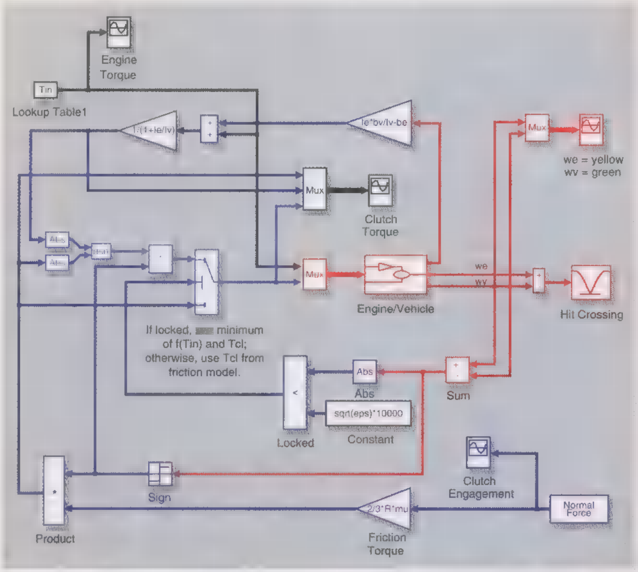

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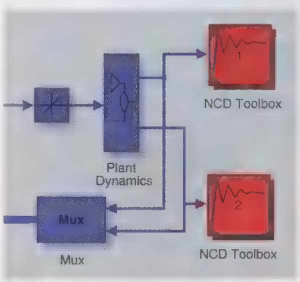

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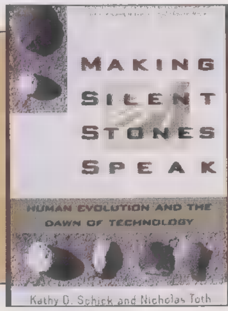
Learning from the Stone Age

KAREN R. ROSENBERG

Making Silent Stones Speak: Human Evolution and the Dawn of Technology. *Schick, Kathy D., and Toth, Nicholas, a Touchstone book published by Simon and Schuster, New York, 1993, 352 pp., $13.*



Readers of *IEEE Spectrum* may be surprised to find two-million-year-old stone tools at the core of anything reviewed in these pages. The authors of this informative and entertaining book, however, would find it entirely appropriate. They see a continuum from the simplest technology of early humans to the late twentieth-century-world of electronics on which we have come to depend. In fact, they contend, even the tool use of nonhumans like mud wasps, Galapagos Island finches, Egyptian vultures, California sea otters, and chimpanzees could be considered technology. They write:

"At this moment we are writing on a portable computer, traveling hundreds of miles per hour through a dark and starry night in the last row of the upper deck of a 747 airliner, on our way to yet another archaeological research project to explore some of humankind's oldest tool-making traditions. There is something philosophically pleasing about exploring the world's most ancient and rudimentary technologies with the assistance of some of the most sophisticated contemporary ones....and, as we hope the reader will come to appreciate, there is no accidental relationship between the two."

For authors Schick and Toth, modern technology is the "legacy of an unbroken chain of learned tool-making and tool-using behavior [which] can be traced back to the dawn of human technology and the emergence of hominid populations that made and used the simplest flaked stone tools some two and a half million years ago on the African continent."

They argue that the centrality of technology to our life-style has had a profound effect on our evolutionary history. "Since tool-making achieved this critical role in our lives, humans have always lived in a 'technological age,'" they write.

The authors have made this account readable and indeed enjoyable by including short, dramatic narratives of early

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hominids engaged in activities like making stone tools, butchering scavenged animals, and consuming the meat. They also describe the process by which human artifacts, workshops, and trash become archaeological sites, and they explain what it is like to be an archaeologist, both in the field and in the laboratory. Even in geographical terms, the book covers a lot of ground—the authors have done field work in East Africa, China, and the New Guinea Highlands.

Over the last decade or so, paleoanthropologists have written a number of books for a popular audience. What makes this book stand out from the others is its emphasis on the scientific process of archeology, rather than on the petty squabbles and jealousies in our field, which so often (unfortunately) dominate the popular media. The authors approach stone tools as part of a technological and cultural system, instead of simply as isolated objects of intrinsic interest. Their analysis is organized around various stages in the manufacture and use of such tools, including the acquisition and transport of raw material, tool production, tool modification during use, as well as ultimately, their discarding and archaeological discovery.

What I particularly like is that this book answers the question, "How do archeologists learn from bits of stone and trash how people lived millions of years ago?" It is not just about what happened in human prehistory, but about the process of discovery of what happened in human prehistory. The authors put a lot of effort into unraveling the process by which archeologists go from lumps of stone, which they recognize as having been worked by early humans (their "data"), to statements about the behavior of our ancestors two-and-a-half-million years ago and the importance of technology in their (and our) life-styles.

Focusing primarily, though by no means exclusively, on their own research, Schick and Toth describe several approaches they have used. Besides dealing with tool use and tool-making in other animals, as mentioned above, they explain the stages of analysis of artifacts collected from archeological sites.

Finally, they discuss their involvement in "experimental archeology." In order to understand how stone tools were manufactured, they spent many long hours making their own stone tools. They then used the tools to understand how the artifacts might work in different functional contexts and to examine the wear that such use might leave on them.

In one memorable description, the authors tell of butchering the "world's largest terrestrial mammal," an elephant, using the "world's simplest flaked stone technology." Noting that the elephant died of natural causes," the authors admit that "the sight of a twelve-thousand-pound animal carcass the size of a Winnebago can be quite intimidating," but report their amazement that the small lava flakes they had produced were extremely effective at cutting up the remains.

To ascertain how archaeological sites come to be buried, the authors created experimental sites in various locations. They labeled and recorded the position of "artifacts" and then examined the region following a flood to determine what effects the event had had on the placement and condition of the stone tools, animal bones, and the site itself.

Even to look at, this book is both infor-

books

mative and fun. Figures illustrating stone tools and animal and early human bones, as well as archaeologists at their work, adorn nearly a third of the pages. But the authors are at bottom quite serious.

They argue that archaeology has something substantive to contribute to the world outside the confines of studies of stone age tools. After reminding readers that extinction is the norm for species, they propose that "our hope of continuing as a species into the future will lie in our ability to come to grips with our technological systems and to overcome their potentially destructive consequences."

To win through, they contend, people must gain an understanding of how technology came to be so central to our way of life. This book is a fine and engaging survey of the beginnings of that process.

Karen R. Rosenberg is an associate professor in the department of anthropology at the University of Delaware in Newark. Her research focuses on the fossil evidence for human evolution. She has studied human skeletal remains in Central Europe, the Middle East, Southeast Asia, China, and the Delmarva Peninsula in the United States. Her published work include writings on prehistoric health and diet in the Mid-Atlantic region, Neanderthal pelvic morphology, and the evolution of modern human childbirth.

recent books

Worldwide Advances in Communication Networks. Ed. *Jabbari, Bijan,* Plenum Publishing, New York, 1994, 185 pp., $69.50.

Coherent Lightwave Communications Systems. *Ryu, Shiro,* Artech House, Boston, 1995, 283 pp., $79.

Optical Engineering Fundamentals. *Walker, Bruce H.,* McGraw-Hill, New York, 1995, 341 pp., $40.

Algorithmic Learning. *Hutchinson, Alan,* Oxford University Press, New York, 1994, 434 pp., $90 (hardcover), $42.50 (paperback).

Automotive Sensors. *Westbrook, M.H.,* and *Turner, J.D.,* Institute of Physics Publishing, Philadelphia, 1994, 272 pp., $149.

Operational Amplifier Circuits: Analysis and Design. *Nelson, John C.C.,* Butterworth-Heinemann, Woburn, Mass., 1995, 138 pp., $22.95.

Thermal Sensors. *Meijer, G.C.M.,* and *van Herwaarden, A.W.,* Institute of Physics Publishing, Philadelphia, 1994, 320 pp., $150.

Advanced Microprocessors, 2nd edition. *Tabak, Daniel,* McGraw-Hill, New York, 1995, 523 pp., $60.

Adventures in Space Simulator: The Ultimate Desktop Astronaut's Guide. *Fjermedal, Grant,* Microsoft Press, Redmond, Wash., 1994, 245 pp., $22.95.

Smart Highways, Smart Cars. *Whelan, Richard,* Artech House, Boston, 1995, 231 pp., $59.

Two-Dimensional Imaging. *Bracewell, Ronald N.,* Prentice Hall, Engelwood Cliffs, N.J., 1995, 689 pp., $66.67.

The CG-FTT Method: Application of Signal Processing Techniques to Electromagnetics. *Catedra, Manuel F., et al.,* Artech House, Boston, 1995, 361 pp., $95.

Bugs in Writing: A Guide to Debugging Your Prose. *Dupre, Lyn,* Addison-Wesley, Chicago, 1995, 649 pp., $19.95.

Mobile Telecommunications: Emerging European Markets. Eds. *Schenk, Karl-Ernst, et al.,* Artech House, Boston, 1995, 328 pp., $69.

UNIX System Administration Handbook, 2nd edition. *Nemeth, Evi, et al.,* Prentice Hall, Englewood Cliffs, N.J., 1995, 361 pp., $48 (with CD ROM included).

Migrating to Object Technology. *Graham, Ian,* Addison-Wesley, Reading, Mass., 1995, 552 pp., $45.25.

The Handbook of Optics, 2nd edition, Vol. I: Fundamentals, Techniques, and Design; Vol. II: Devices, Measurements, and Properties. Ed. *Bass, Michael, et al.,* McGraw-Hill, New York, 1995, 1400 and 1200 pp., respectively, $99.50 each.

How to Solve Problems: For Success in Freshman Physics, Engineering, and Beyond, 4th edition. *Scarl, Donald,* Dosoris Press, Glen Cove, N.Y., 1994, 127 pp., $8.95.

The Future of Software. Ed. *Leebaert, Derek,* MIT Press, Cambridge, Mass., 1995, 300 pp., $24.95.

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Virtual Reality International Symposium (NN, C); March 11–15; Sheraton Imperial Hotel and Convention Center, Research Triangle Park, N.C.; Jim Cone, 2603 Main St., Suite 690, Irvine, CA 92714; 714-752-8205; fax, -752-7444; e-mail, 74710.2266@ compuserve.com.

Ultrafast Electronics and Optoelectronics Topical Meeting (ED); March 13–17; Dana Point Resort, California; Ellen Murphy, Optical Society, 2010 Massachusetts Ave., N.W., Washington, DC 20036; 202-416-1995; fax, 202-416-6100.

International Conference on Computer Applications in Engineering and Medicine (C); March 15–17; University Place Hotel, Indianapolis, Ind.; Mohamed El-Sharkawy, Department of Electronics Engineering, Purdue University, 723 W. Michigan St., Indianapolis, IN 46202; 317-274-4559; fax, 317-274-4493; e-mail, elshark@etsun. engr.iupui.edu.

International Forum on High Quality Digital Video and Its Impact (COM, SP); March 16–17; Waseda University, Tokyo; Sadayasu Ono, NTT Optical Networks Systems Laboratories, 1–2356 Take, Yokosuka, Kanagawa, 238–03, Japan; (81+468) 59 3240; fax, 59 3014; e-mail, forum@ ntttsd.ntt.jp.

European Workshop on Materials for Advanced Metalization (ED); March 19–22; Park Hotel Hoflobnitz, Radebeul, Germany; Stefan E. Schulz, TU Chemnitz-Zwickau, Zentrum für Mikrotechnologien, D-09107 Chemnitz, Germany; (49+371) 531 3683; fax, (49+371) 531 3131.

Fourth International Fuzzy Systems Conference (NN); March 20–24; Pacific Convention Plaza, Yokohama, Japan; Life, Siber Hegner Building 4F, 89–1, Yamashita-cho, Naka-ku, Kanagawa 243, Japan; (81+45) 212 8268; fax, (81+45) 212 8255.

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National Radio Science Conference (ED); March 21–23; Alexandria University, Egypt; Ibrahim A. Salem, 17 Elqouba St., 3, Roxy Heliopolis, Cairo–11341, Egypt; (20+2) 258 0256; fax, (20+2) 349 8217.

International Conference on Microelectronic Test Structures (ED); March 23–25; New Public Hall, Nara, Japan; Loren W. Linholm, National Institute of Standards and Technology, B-360 Technical Building, Gaithersburg, MD 20899; 301-975-2052; fax, 301-948-4081; e-mail, linholm@sed.eeel.nist.gov.

Signal Processing Workshop (MD/DC Chapter SP, NCAC); March 24–25; University of the District of Columbia, Van Ness Campus, Washington, D.C.; Edgar Neal, 11809 Collins Dr., Germantown, MD 20876; 301-258-8301; fax, 301-258-9163; e-mail, rpierce@oasys.dt.navy.mil.

Seventh Workshop on Local and Metropolitan Area Networks (COM); March 26–29; Hawk's Cay Resort and Marina, Duck Key, Fla.; Yoram Ofek, IBM Corp., T. J. Watson Research Center, Box 704, Yorktown Heights, NY 10598; 914-784-7085; fax, -6205.

Southeastcon '95 (Region 3, East NC); March 26–29; North Raleigh Hilton,

Raleigh, N.C.; Charles J. Lord, 108 Huntington Circle, Cary, NC 27513; 919-469-9682; e-mail, c.j.lord@ieee.org.

Interpack '95: Towards Failure Free, Low Cost Electronic Packaging (CPMT); March 26–30; Westin Maui, Lahaina, Hawaii; Avram Bar-Cohen, Department of Mechanical Engineering, University of Minnesota, 111 Church St., S.E., Minneapolis, MN 55455; 612-626-7244; fax, 612-624-1398.

International Symposium on Requirements Engineering—RE '95 (C); March 27–29; York University, UK; M. D. Harrison, Department of Computer Science, University of York, Heslington York, Y01 5DD, England; (44+904) 432 732; fax, 432 767; e-mail, math@minster.york.ac.uk.

International Verilog HDL Conference (C); March 27–29; Santa Clara Convention Center, Calif.; Hamid Butt, Vertex Semiconductor, 1060 Rincon Circle, San Jose, CA 95131; 408-526-2715; fax, -9286; e-mail, hamid@ventex.com.

Data Compression Conference—DCC '95 (C); March 28–30; Cliff Lodge, Snowbird, Utah; James A. Storer, Computer Science Department, Brandeis University, Waltham, MA 02254; 617-736-2714; fax, -736-2741; e-mail, storer@cs.brandeis.edu.

Fourth International Workshop on Responsive Computer Systems (CS); March 29–31; Hotel President, Berlin; Volker Tschammer, GMD-Fokus, Hardenbergplatz 2, D-10623 Berlin, Germany; (49+30) 254 99 226; fax, (49+30) 254 99 202; e-mail, tschammer@fokus.berlin,gmd.d400.d.

april

Infocom '95 (C, COM); April 2–6; Park Plaza Hotel, Boston; Celia Desmond, Stentor, Floor 6B, 33 City Center Dr., Mississauga, ON L5B 2N5, Canada; 416-615-6507; fax, 416-615-8421.

International Conference on Telecommunications (COM, Indonesia Section); April 3–5; Bali Hilton Hotel, Indonesia; John Pearson, Electronic Engineering Department, Kings College London, Strand, London WC2R 2LS, England; (44+71) 873 2850; fax, (44+71) 836 4781.

International Reliability Physics Symposium (ED); April 3–6; Riviera Hotel, Las Vegas, Nev.; Joseph W. McPherson, Texas Instruments, Box 655012, M/S 385, 13353 Floyd Rd., Dallas, TX 75243; 214-995-2183; fax, -2932.

Second Topical Symposium on Combined Optical, Microwave, Earth and Atmosphere Sensing (GRS, LEO, MTT); April 3–6; Atlanta Renaissance, Georgia; Melissa Estrin, IEEE/LEOS, 445 Hoes Lane, Box 1331, Piscataway, NJ 08855; 908-562-3896; fax, -8434; e-mail, m.estrin@ieee.org.

Joint Railroad Conference (VT); April 4–6; Baltimore Marriott Inner Harbor Hotel, Maryland; Richard C. Tansill, De Leuw, Cather & Co., 1133 15th St., N.W., Washington, DC 20005-2701; 202-775-3320; fax, 202-775-3389.

14th Southern Biomedical Engineering Conference (EMB); April 8–9; Holiday Inn Downtown, Shreveport, La.;

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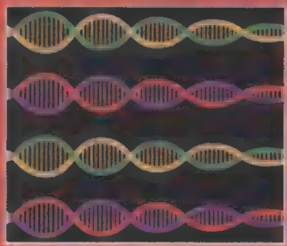

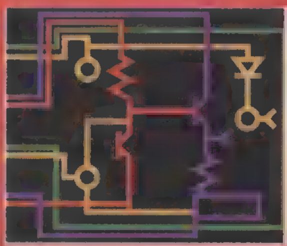

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Conference on Computational Intelligence for Financial Engineering—CIFE (C, NN); April 9–11; Crown Plaza, New York City; Scott Mathews, 14920 24th Ave., S.E., Bothell, WA 98012–5718; 206-485-0442; fax, 714-752-7444; e-mail, 74710. 2266@ compuserv.com.

28th Annual Simulation Symposium (C); April 9–13; Crescent Hotel, Phoenix, Ariz.; Enrique V. Kortright, Computer Science Department, Nichols State University, Thibodaux, LA 70310; 504-448-4406; fax, -448-4927; e-mail, ek@reality.nich.edu.

First Malaysia International Conference on Electromagnetic Compatibility—ICEMC '95 KUL (Malaysia Section); April 11–13; Shangri-La Hotel, Kuala Lumpur; Hussein Ahmad, Universiti Teknologi Malaysia, Fakulti Kejuruteraan Elektrik, Jalan Semarak, 54100 Kuala Lumpur, Malaysia; (60+3) 290 4219; fax, (60+3) 293 4844.

Fourth International Symposium on Database Systems for Advanced Applications (C); April 11–14; National University of Singapore; Chung-Kwong Yuen, Department of IS&CS, National University of Singapore, Lower Kent Ridge 0511, Singapore; (65) 772 2831; fax, (65) 779 4580; e-mail, yuenck@iscs.mus.sg.

Applications and Science of Artificial Neural Networks VI—SPIE (NN); April 17–21; Marriott's Orlando World Center, Florida; D. Ruck, AFIT/ENG, Building 642, 2950 P St., Wright Patterson AFB, OH 45433; 513-255-6565, ext. 4285; fax, 513-476-4055; e-mail, d.ruck@ieee.org.

Intermag '95 (MAG); April 18–21; Marriott Rivercenter Hotel, San Antonio, Texas; Diane Suiters, Courtesy Associates, 655 15th St., N.W., Suite 300, Washington, DC 20005; 202-639-5088; fax, 202-347-6109.

Fifth International Workshop on Network and Operating System Support for Digital Audio and Video—Nossdav '95 (COM); April 19–21; New England Center, Durham, N.H.; Thomas D. C. Little, Boston University, College of Engineering, 44 Cummington St., Boston, MA 02215; 617-353-9877; fax, 617-353-6440.

Information Theory Workshop on Information Theory, Multiple Access and Queueing (IT); April 19–21; Adam's Mark Hotel, St. Louis, Mo.; Leandros Tassiulas, Polytechnic University, 6 Metrotech Center, Brooklyn, NY 11201; 718-260-3511; fax, 718-260-3074.

Workshop on Electronic Design Processes (C, CAS); April 19–21; Breckinridge Hilton Hotel, Colorado; William J. McCalla, Cadence Design Systems, 555 River Oaks Parkway, San

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Jose, CA 95134; 408-428-5600; fax, 408-894-3479.

First International Conference on Algorithms and Architectures for Parallel Processing (Queensland, Singapore Section, et al.); April 19–22; Mayfair Crest International Hotel, Brisbane, Australia; C. W. Chan, Department of Electrical and Computer Engineering, University of Queensland, Queensland–4072, Australia; (61+7) 365 3985; fax, (61+7) 365 4999.

Fourth Workshop on Enabling Technologies: Infrastructure for Collaborative Enterprises (C); April 20–22; Coolfont Resort and Conference Center, Berkeley Springs, W. Va.; K. Joseph Cleetus, CERC, Box 6506, West Virginia University, Morgantown, WV 26506; 304-293-7226; fax, 304-293-7541; e-mail, jocle@cerc. wvu.edu.

International Workshop on Charge-Coupled Devices and Advanced Image Sensors (ED); April 20–22; Dana Point Resort, California; Eric R. Fossum, Jet Propulsion Laboratory, M/A 300–315, 4800 Oak Grove Dr., Pasadena, CA 91109; 818-393-0045; fax, 818-354-3128.

Robotics and Automation (RA); April 22–28; Minneapolis Hilton and Towers, Minnesota; Norman Caplan, National Science Foundation, BES, Room 565, 4201 Wilson Blvd., Arlington, VA 22230; 703-306-1318; fax, -306-0312; e-mail, ncaplan@note.nsf.gov.

Instrumentation and Measurement Technology Conference—IMTC '95 (IM, Boston Section); April 24–26; Westin Hotel, Waltham, Mass.; Robert Myers, Conference Coordinator, 3685 Motor Ave., Suite 240, Los Angeles, CA 90034; 310-287-1463; fax, 310-287-1851.

International Computer Performance and Dependability Symposium (C); April 24–26; University of Erlangen–Numberg, Germany; Wolfgang Hohl, Informatik III, Universität Erlangen–Numberg, Martensstrasse 3, D-91058 Erlangen, Germany; (91+31) 857 010; fax, (91+31) 393 88.

17th International Conference on Software Engineering (C); April 24–28; Westin Hotel, Seattle, Wash.; Dewayne Perry, AT&T Bell Laboratories, 600 Mountain Ave., Murray Hill, NJ 07974; 908-582-2529; fax, 908-582-7550; e-mail, dep@research.att.com.

Technical Conference on Rubber and Plastics Industry (IA, Akron Section); April 25–26; Quaker Square Hilton, Akron, Ohio; Kenneth Kling, c/o MC2 Inc., 3201 East Royalton Rd., Broadview Heights, OH 44147; 216-526-6511; fax, 216-526-8474.

International Parallel Processing Symposium (C); April 25–28; Fess Parker's Red Lion Resort, Santa Barbara, Calif.; Viktor K. Prasanna, Department of Electrical Engineering Systems, EEB-244, University of South Carolina, Los Angeles, CA 90089–2562; 213-740-4483; fax, 213-740-4449; e-mail, prasanna@halcyon,usc.edu.

Princeton/Central Jersey Sarnoff Symposium (LEO, MTT et al.); April 28; David Sarnoff Research Center, Princeton, N.J.; Samantha Phillips, IEEE/LEOS, 445 Hoes Lane, Box 1331, Piscataway, NJ 08855–1331; 908-562-3894; fax, 908-562-8434; e-mail, s.phillips@ieee.org.

International Symposium on Circuits and Systems—Iscas '95 (CAS); April 28–May 6; Sheraton Seattle Hotel, Washington; Meeting Management, Iscas '95, 2603 Main St., Suite 690, Irvine, CA 92714; 800-321-6338; fax, 714-752-7444.

Rural Electric Power Conference (IA); April 30–May 2; Sheraton Music City Hotel, Nashville, Tenn.; Gregory P. Woodsmall, Northern Virginia Electric Cooperative, 5399 Wellington Rd., Box 310, Gainesville, VA 22065; 703-754-6700; fax, 703-754-6777.

13th VLSI Test Symposium (C); April 30–May 3; Princeton Marriott Hotel, New Jersey; Prab Varma, CrossCheck Technology, 2833 Junction Ave., Suite 100, San Jose, CA 95134; 408-432-9200; fax, 408-432-0907; e-mail, prab@crosscheck.com.

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International Symposium on Electronics and the Environment (TAB); May 1–3; Hyatt Regency, Orlando, Fla.; Conference Registrar, IEEE Technical Activities, 445 Hoes Lane, Box 1331, Piscataway, NJ 08855–1331; 908-562-3878; fax, 908-981-1769; e-mail, conferenceregistrar@ieee.org.

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Coupled Devices and Advanced Image Sensors (ED); April 20–22; Dana Point Resort, California; Eric R. Fossum, Jet Propulsion Laboratory, M/A 300–315, 4800 Oak Grove Dr., Pasadena, CA 91109; 818-393-0045; fax, 818-354-3128.

Robotics and Automation (RA); April 22–28; Minneapolis Hilton and Towers, Minnesota; Norman Caplan, National Science Foundation, BES, Room 565, 4201 Wilson Blvd., Arlington, VA 22230; 703-306-1318; fax, -306-0312; e-mail, ncaplan@note.nsf.gov.

Instrumentation and Measurement Technology Conference—IMTC '95 (IM, Boston Section); April 24–26; Westin Hotel, Waltham, Mass.; Robert Myers, Conference Coordinator, 3685 Motor Ave., Suite 240, Los Angeles, CA 90034; 310-287-1463; fax, 310-287-1851.

International Computer Performance and Dependability Symposium (C); April 24–26; University of Erlangen–Numberg, Germany; Wolfgang Hohl, Informatik III, Universität Erlangen–Numberg, Martensstrasse 3, D-91058 Erlangen, Germany; (91+31) 857 010; fax, (91+31) 393 88.

17th International Conference on Software Engineering (C); April 24–28; Westin Hotel, Seattle, Wash.; Dewayne Perry, AT&T Bell Laboratories, 600 Mountain Ave., Murray

908-562-3894; fax, 908-562-8434; e-mail, s.phillips@ieee.org.

International Symposium on Circuits and Systems—Iscas '95 (CAS); April 28–May 6; Sheraton Seattle Hotel, Washington; Meeting Management, Iscas '95, 2603 Main St., Suite 690, Irvine, CA 92714; 800-321-6338; fax, 714-752-7444.

Rural Electric Power Conference (IA); April 30–May 2; Sheraton Music City Hotel, Nashville, Tenn.; Gregory P. Woodsmall, Northern Virginia Electric Cooperative, 5399 Wellington Rd., Box 310, Gainesville, VA 22065; 703-754-6700; fax, 703-754-6777.

13th VLSI Test Symposium (C); April 30–May 3; Princeton Marriott Hotel, New Jersey; Prab Varma, CrossCheck Technology, 2833 Junction Ave., Suite 100, San Jose, CA 95134; 408-432-9200; fax, 408-432-0907; e-mail, prab@crosscheck.com.

may

International Symposium on Electronics and the Environment (TAB); May 1–3; Hyatt Regency, Orlando, Fla.; Conference Registrar, IEEE Technical Activities, 445 Hoes Lane, Box 1331, Piscataway, NJ 08855–1331; 908-562-3878; fax, 908-981-1769; e-mail, conferenceregistrar@ieee.org.

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washington watch

Republicans challenge White House on science

Administration officials can expect cuts in science and technology programs, they were told by the new chairman of the House Committee on Science. "We have to get past the idea of these things as [permanently funded] government programs," said Robert S. Walker (R-Pa.) at his committee's first public hearing, held Jan.6.

The White House Science Advisor, John Gibbons, vowed in a statement to "stand and fight" against the proposed cuts, which as outlined, he said, could cause a "wholesale, devastating retreat" in the U.S. science and technology enterprise "on which our future depends."

After testimony from the chiefs of five key agencies, Walker urged them to find other ways of spurring research in industry, such as deregulation or tax incentives for specific technology development.

A statement by leaders in industry and academia distributed by the Council on Competitiveness noted that historically, government has given bipartisan support to science and technology, funding about half the nation's R&D. It called for the creation of tax incentives and a regulatory climate that would be more supportive of R&D.

For copies of testimonies, call the IEEE Washington office at 202-785-0017.

A new influence on R&D

A former advocate of the superconducting supercollider and still a supporter of the space station, House Science Committee chairman Robert S. Walker (R.-Pa.) said he wants to kill the Advanced Technology Program, which he called a "font of national industrial policy."

He also expects to hold hearings on the Mission to Planet Earth and the Global Warming research programs, which in his view may be supporting questionable science. He said that basic (rather than applied) research should be the focus of the National Science Foundation, which since the 1980s has sponsored a greater share of applied research.

As to a Republican proposal to eliminate Congress' Office of Technology Assessment, Walker said that he is open to the idea, but cited the value to Congress of having independent technical advice. [See "The Office of Technology Assessment: an endangered species worth saving," *IEEE Spectrum*, February 1995, pp. 13–14.] If the office is to stay, he suggest-

ed that its reports be more timely and better tailored to the authorization process, according to a report by IEEE-USA lobbyist Chris Brantley.

The American Association of Engineering Societies had lobbied for a name less narrow than the House Science Committee (formerly it was the House Committee on Science, Space and Technology). Still, the four subcommittees do reflect a broader agenda: Space and Aeronautics, Basic Research, Energy and Environment, and Technology.

Walker, 54, is a former high school teacher who was first elected to Congress in 1976. In 1989 he was brought into the House Republican leadership by then Minority Whip Newt Gingrich. He also serves as vice chairman of the influential House Budget Committee.

New rules for foreign hires

Final regulations recently published by the Labor Department are likely to "strengthen protections for U.S. workers, including engineers and scientists," while preventing the "exploitation of foreign professionals," according to the IEEE-USA.

Among the requirements are that employers tell the department how many foreign nationals they intend to hire, where and for how long the aliens are to be employed, and how much they will be paid. Greater detail on the methodology used by companies to determine the wages of foreign professionals is also required.

For more information, contact Vin O'Neill at IEEE-USA at 202-785-0017 or by Internet at v.oneill@ieee.org.

Ethics in fuzzy areas

Every researcher knows plagiarism is not good practice, but what about the sharing of research materials or fair contracts for industrial sponsorship of academic research? These and other fuzzy ethical areas are tackled in a revised guide by a committee of the National Academies of Science and Engineering and the Institute of Medicine.

So long as the core virtues of honesty, skepticism, fairness, collegiality, and openness prevail, the research enterprise will have "unparalleled productivity and creativity," states the 40-page booklet. Titled "On Being a Scientist," it is appropriate for engineers, too.

Copies are being distributed to graduate students free of charge. For others, the price is $5 from the National Academy Press at 202-334-3313 or 800-624-6242.

Green aid for small firms

The goal of a new Commerce Department program is to help small and medium-sized U.S. manufacturers to solve environmental issues before the issues become compliance problems. There are approximately 370 000 such companies.

The program is being administered by the department's National Institute of Standards and Technology (NIST) in cooperation with the Environmental Protection Agency. Proposals are sought in three areas: integration of environmental services in manufacturing extension centers; technical assistance tools; and pilot programs for industry-specific pollution prevention.

There are currently 44 manufacturing extension centers and plans for 100 nationwide by 1997. For more information, contact NIST by phone at 301-975-5020.

JOHN A. ADAM, Washington Editor

Circle No. 28

recent books

Continued from p. 14

PowerBuilder: Building Client Server Applications. *Mahler, Paul*, Prentice Hall, Englewood Cliffs, N.J., 1995, 440 pp., $34.95.

Simplified Design of Switching Power Supplies. *Lenk, John D.*, Butterworth-Heinemann, Woburn, Mass., 1995, 224 pp., $39.95.

Progress in Simulation, Vol. 2. Eds. *Zobrist, George W.*, and *Leonard, James V.*, Ablex Publishing, Norwood, N.J., 1994, 412 pp., $65.

Controlling Technology: Ethics and the Responsible Engineer, 2nd edition. *Unger, Stephen H.*, John Wiley & Sons, Somerset, N.J., 1994, 353 pp., $34.95.

The UNIX Philosophy. *Gancarz, Mike*, Butterworth-Heinemann, Woburn, Mass., 1995, 151 pp., $19.95.

Developing Microsoft Excel 5 Solutions. *Wells, Eric*, Microsoft Press, Redmond, Wash., 1995, 712 pp., $39.95.

Video Compression for Multimedia. *Ozer, Jan*, Academic Press, New York, 1995, 387 pp., $39.95.

The New Rules of the Job Search Game: Why Today's Managers Hire...and Why They Don't. *Larson, Jackie*, and *Comstock, Cheri*, Adams Publishing, Holbrook, Mass., 1994, 254 pp., $10.

Circuits of the Mind. *Valiant, Leslie G.*, Oxford University Press, New York, 1994, 237 pp., $49.95.

AIX RS/6000 System and Administration Guide. *DeRoest, James W.*, McGraw-Hill, New York, 1995, 464 pp., $39.95.

Field Programmable Gate Arrays: Reconfigurable Logic for Rapid Prototyping and Implementation of Digital Systems. *Oldfield, John R.*, and *Dorf, Richard C.*, John Wiley & Sons, New York, 1995, 327 pp., $59.95.

The ISDN Literacy Book. *Hopkins, Gerald L.*, Addison-Wesley, New York, 1995, 367 pp., $34.50.

Nikola Tesla On His Work With Alternating Currents and Their Application to Wireless Telegraphy, Telephony, and Transmission of Power. Ed. *Anderson, Leland I.*, Twenty First Century Books, Breckenridge, Colo., 1994, 237 pp., $40.

Using Digital Video. *Luther, Arch C.*, Academic Press, New York, 1995, 297 pp., $34.95.

Text Algorithms. *Crochemore, Maxime*, and *Rytter, Wojciech*, Oxford University Press, New York, 1994, 412 pp., $95.

The Discipline of Market Leaders: Choose Your Customers, Narrow Your Focus, Dominate Your Market. *Treacy, Michael*, and *Wiersema, Fred*, Addison-Wesley, New York, 1995, 208 pp., $25.

Nikola Tesla: Lecture Before the New York Academy of Sciences—April 6, 1897. Ed. *Anderson, Leland I.*, Twenty

recent books

First Century Books, Breckenridge, Colo., 1994, 122 pp., $21.95 (hardcover), $12.95 (paperback).

Epitaxial Microstructures. Ed. *Gossard, Arthur C.*, Academic Press, New York, 1994, 440 pp., $119.

A Discipline for Software Engineering. *Humphrey, Watts S.*, Addison-Wesley, New York, 1995, 789 pp., $47.50.

ATM Systems Design: The Hitch-Hiker's Guide. *Rahman, Mohammad*, Dallas Engineers, Dallas, 1994, 212 pp., $60 (hardcover), $40 (paperback).

The Particle Garden: Our Universe as Understood by Particle Physicists. *Kane, Gordon*, Addison-Wesley, New York, 1995, 224 pp., $22.

Building a Successful Board-Test Strategy. *Scheiber, Stephen F.*, Butterworth-Heinemann, Boston, 1995, 286 pp., $44.95.

The Product Development Challenge. Ed. *Clark, Kim B.*, and *Wheelwright, Steven C.*, Harvard Business School Press, New York, 1995, 448 pp., $32.50.

The Sand Dollar and the Slide Rule: Drawing Blueprints from Nature. *Willis, Delta*, Addison-Wesley, New York, 1995, 288 pp., $23.

Broadband Patch Antennas. *Zurcher, Jean-Francois*, and *Gardiol, Fred E.*, Artech House, Boston, 1995, 211 pp., $69.

Every Manager's Guide to Information Technology: A Glossary of Key Terms & Concepts for Today's Business Leader. *Keen, Peter G.W.*, Harvard Business School Press, New York, 1995, 304 pp., $18.95.

Phase Transformations and Ablation in Laser-Treated Solids. *Sobol, Emil N.*, John Wiley & Sons, New York, 1995, 332 pp., $59.95.

The Future of Software. Ed. *Leebaert, Derek*, MIT Press, Cambridge, Mass., 1995, 300 pp., $24.95.

High-Power Microwave Systems and Effects. *Taylor, Clayborne D.*, and *Giri, D.V.*, Taylor & Francis, Bristol, Pa., 1994, 203 pp., $59.50.

Quality Planning, Control, and Improvement in Research and Development. Ed. *Roberts, George W.*, Marcel Dekker, New York, 1995, 384 pp., $99.75.

Thinking in Complexity: The Complex Dynamics of Matter, Mind, and Mankind. *Mainzer, Klaus*, Springer-Verlag, New York, 1994, 329 pp., $34.50.

Personal Communication Systems and Technologies. Ed. *Gardiner, John*, and *West, Barry*, Artech House, Boston, 1995, 242 pp., $59.

Werner von Siemens, Inventor and International Entrepreneur. *Feldenkirchen, Wilfried*, Ohio State University Press, Columbus, Ohio, 1994, 206 pp., $19.95 (hardcover), $12.50 (paperback).

Manufacturing Renaissance. Eds. *Pisano, Gary P.*, and *Hayes, Robert H.*, Harvard Business School Press, New York, 1995, 352 pp., $29.95.

Electronic Mail. *Palme, Jacob*, Artech House, Boston, 1995, 274 pp., $54.

Handbook of Electric Motors. Ed. *Engelmann, Richard H.*, and *Middendorf, William H.*, Marcel Dekker, New York, 1995, 832 pp., $150.

Animation Techniques in Win32. *Thompson, Nigel*, Microsoft Press, Redmond, Wash., 1995, 288 pp., $39.95.

Introducing Microsoft Windows 95. *Microsoft Corp.*, Microsoft Press, Redmond, Wash., 1995, 368 pp., $12.95.

Computer Visualization: Graphics Techniques for Scientific and Engineering Analysis. *Gallagher, Richard S.*, CRC Press, Boca Raton, Fla., 1995, 312 pp., $69.95.

VLSI for Neural Networks and Artificial Intelligence. Eds. *Delgado-Frias, Jose G.*, and *Moore, William R.*, Plenum Press, New York, 1994, 320 pp., $85.

Intermediate Classical Dynamics with Applications to Beam Physics. *Michelotti, Leo*, John Wiley & Sons, New York, 1995, 340 pp., $59.95.

Writing Bug-Free C Code for Windows? A Programming Style that Automatically Detects Bugs in C Code. *Jongerius, Jerry*, Prentice Hall, Englewood Cliffs, N.J., 1995, 218 pp., $29.

Handbook of Materials and Techniques for Vacuum Devices. *Kohn,*

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EV watch

Government report misrepresents EVs

In response to a request from the Committee on Science, Space, and Technology of the U.S. House of Representatives, the General Accounting Office (GAO) has conducted a study of development and commercialization programs for electric vehicles in the United States and elsewhere. In December, it presented its findings in a report titled *Electric vehicles: Likely consequences of U.S. and other nations' programs and policies*. (For a free copy, call the GAO at 202-512-6000; fax, 301-258-4066.)

The report examines current barriers to the widespread use of electric vehicles and reviews the EV policies and programs of seven countries, as well as the national and regional effects of EVs on economics, energy, and the environment.

It makes some useful observations. In particular, its analysis of the potential market for EVs contrasts the rather optimistic figures based on what is technically possible with the less promising results obtained on the basis of consumer-preference studies. The report concluded that neither approach by itself provided much useful information.

Unfortunately, the document is also so full of bias and outright errors as to make EVs appear much less attractive than they actually are. For example, in discussing the environmental effects of EVs in New York City, the report states that, in the year 2000, the utility that serves the city, Consolidated Edison Co. of New York Inc., plans to obtain more than half of its off-peak electricity from "highly polluting coal and oil."

That is just not the case, according to Martin Gitten, Con Edison's assistant director of public information: in 1993, the company got *about 10 percent* of its electricity from coal (the 1994 figures are as yet not available), and it has been forbidden by law since 1973 to burn coal at any of its own plants. Furthermore, he told *IEEE Spectrum*, the company is restricted to burning only low-sulfur oil (oil containing less than 0.3 percent sulfur) and today burns about half as much as it did in 1990, as it switches increasingly to natural gas.

In addition, the GAO report states that "...as of 1990, Denver, New York, and Los Angeles used coal as their primary high-demand off-peak fuel source." Ignoring the question of how something can be both "high-demand" and "off-peak," the fact is that, in recent years, including 1990, Con Edison has derived less than 10 percent of its electricity from coal. Moreover, none of that coal was burned in densely populated New York City itself.

In a review of the report, included in an appendix, the Department of Energy has several criticisms to make. One of special interest was that the report's findings on sulfur dioxide and nitrogen oxide emissions associated with EVs do not take into account the expected impact of the Clean Air Act Amendments of 1990. The DOE said, in part, "The electric utility industry is required by the Clean Air Act Amendments to make significant reductions in emissions of oxides of nitrogen and sulfur. Specifically, sulfur oxide emissions are capped. Thus, the electric utility industry will not be allowed to increase emissions of sulfur oxides in supplying additional energy for electric vehicles."

The GAO's reaction to that observation was to point out that "...costs will increase if additional emissions must be monitored and controlled at the power plant." True, but is that a reason to ignore the law and misrepresent the facts?

The GAO went on to state: "Moreover, other nations we reviewed do not all have air quality restrictions as stringent as those in the United States. Thus, the introduction of electric vehicles in these nations could contribute to increased global emissions of nitrogen oxides and sulfur dioxide." Again, is this a reason to ignore pollution-reduction efforts within the United States?

The report tries hard to make EVs appear as outrageously expensive and as unsafe as it possibly could. In particular, it exaggerates the potential for disaster of sodium-sulfur batteries, ignoring the num erous safety features designed into them. Those features have allowed the batteries to pass without problem such demanding tests as impalement on an upended steel beam and being sliced in half by a guillotine-like device.

What is most disturbing about *Electric vehicles*, however, is not so much the factual errors, since anyone may make a mistake or two. Rather, it is the purposefully anti-EV propagandist tone—note, for instance, the application of a phrase like "highly polluting coal and oil" to rather clean 0.3-percent oil. The authors were clearly seeking to taint clean oil with the sooty image of an old coal-fired plant. This is not what we expect from a supposedly impartial Government agency.

12th International EV Symposium is largest ever

The 12th International Electric Vehicle Symposium and Electric Vehicle Exposition held this past Dec. 3–7 in Anaheim, Calif., was by far the largest in the meeting's 25-year history. According to the Electric Vehicle Association of the Americas (EVAA), under whose auspices the event was presented, it attracted more than 1600 members of the lay public in addition to 1305 registrants and over 200 journalists.

The growth in attendance at the meeting confirms what most of us knew already: that interest in EVs is on the rise. Beyond that, according to Victor Wouk, a consultant to EV Watch and one of the few attendees at EVS-12 who was also present at EVS-1 in 1969, it also served to illustrate another fact—that, in his words, "At long last reliable EVs are available and may be purchased with confidence." In the early days, he said, the cars were built by people perhaps best described as enthusiasts. Today, they are designed by competent engineers. The only questions that remain, he opined, are "Will they sell?" and "Will they satisfy their purchasers?"

In addition to the usual static exhibits, EVS-12 featured more than a dozen EVs on which visitors could take rides in the extensive Disneyland parking lot. It also boasted more than 200 papers on political, environmental, and economic issues, as well as on purely technical topics.

The symposium and exhibition is a biannual event. EVS-11 was held in 1992 in Florence, Italy. The next one, EVS-13, will be held in Osaka, Japan, Oct. 13–16, 1996, under the auspices of the Japan Electric Vehicle Association and the Electric Vehicle Association Asia-Pacific.

As good as Green Stamps

While some people—the folks at the General Accounting Office, for example—may enjoy putting down electric vehicles, there are others who regard them as desirable enough to be used as deal sweeteners. To be specific, the New York Power Authority included 10 electric cars in the package of goodies it offered Westchester County to nail down a 10-year deal under which power for county buildings will be purchased from the authority.

MICHAEL J. RIEZENMAN, Editor
VICTOR WOUK, VICTOR WOUK ASSOCIATES, Consultant

program notes

Look the GIF horse in the mouth

JOHN R. HINES

When CompuServe Inc. threw open its Graphical Interchange Format (GIF) to the computing public, the reasonable expectation was that, by promoting the use of graphics in worldwide computer networks, the Columbus, Ohio, company would secure its position as a prime on-ramp to the Information Highway. Instead, it may have inadvertently turned GIF into a dead horse.

The format's excellence at compacting high-resolution graphical images has won the acceptance of Internet users and vendors alike, who routinely upload, store, and download GIF files. Since its debut in 1987, hundreds of thousands of GIF files have been stored in CompuServe's Graphics Forums and at Internet sites around the globe. This popularity stems from GIF's ability to store images in a lossless but compact format, so they typically occupy half the disk space needed by noncompressed formats like Hewlett-Packard Graphics Language (HPGL) and Encapsulated PostScript (EPS).

GIF derives its compression prowess from Lempel-Ziv-Welch (LZW) technology, which, unbeknownst to GIF users, was patented in 1985 by Unisys Corp., Blue Bell, Pa. Over the years since then, Unisys had licensed LZW to modem manufacturers for data compression, but it was not until January 1993 that the mainframe supplier–turned–seller of management information services told CompuServe that it would have to buy a license for its use of LZW and pay royalties on all code creating GIF format files.

In June 1994 CompuServe finally acquiesced and bought a license from Unisys. Then, in December, CompuServe informed developers of applications that employ GIF coding that they, too, had to obtain LZW licenses and pay royalties. The public outcry, as seen in Internet forum magazines, was swift.

Unisys denied any responsibility for CompuServe's decision to get developers of GIF-based software involved with licenses or royalties. "Unisys did not require CompuServe to pass on any fee to its sublicensees or end users," proclaimed a January press release, adding that, "Such a decision, and the content and timing of CompuServe's advisory, was at their discretion." The same press release stated that "Unisys does not require licensing, or fees to be paid, for non-commercial, nonprofit GIF-based applications, including those for use on the on-line services." Besides not requiring royalties for such so-called freeware, the company has said it will not ask for royalties on commercial software developed before February1995, so that there is no reason for software developers to rush to make product changes to products already released.

Rather than pay Unisys its 1 percent royalty, though, the major vendors of graphics software have for the most part announced plans to drop GIF. Graphics programs typically support five to 10 different graphical file formats. If program developers had to cough up a 1 percent royalty on each of them, they would be handing 5–10 percent of receipts—their entire profits, in some cases—to the format developers.

The leaders' action makes GIF a dead end for smaller commercial developers. Even freeware developers should plan to eliminate GIF viewers and images from new releases because the confused legal situation surrounding GIF puts anyone involved with it at risk of a nuisance lawsuit.

For developers, the most interesting question is which format to use instead. One worth watching is the fledgling Joint Photographic Experts Group (JPEG) file format, which crops up with increasing regularity on the World Wide Web. Although the JPEG format uses a lossy compression algorithm, it can produce very small files that are just the thing for reducing file transmission costs by an order of magnitude.

Software on the air

The wide availability of high-quality training on topics related to Unix is one reason why the operating system and its associated protocol, TCP/IP, have dominated high-end computing. For example, Sun Microsystems invests heavily in Unix and TCP/IP courses supplied by National Technology University (NTU) in Fort Collins, Colo. NTU is a consortium of universities that offers courses covering a broad range of technical topics. It distributes both continuing education courses and university degree courses on videotape or in real time by satellite.

Now Microsoft Corp. has decided to air courses over its own satellite network, Microsoft TV (MSTV). MSTV broadcasts directly to developers and end users at sites with satellite antennas. Anyone without access to an antenna may view the courses at a local Microsoft Solution Provider.

One- or two-hour courses on Microsoft software are initially to be available once a week, on Tuesdays or Thursdays, at 8 a.m. PST. The spring 1995 courses focus on Windows 95 and on client-server topics from the Internet to the Microsoft BackOffice; training on other products is to be offered as demand increases. Microsoft has also announced that PCTV will distribute its courses through the Mind Extension University channel on its cable subsidiary, the Jones Computer Network.

NTU courses typically cost US \$20–\$40 per hour per individual, but Microsoft TV courses are free, although users are required to obtain a site license before videotaping courses. *Contact: NTU, 700 Centre Ave., Fort Collins, CO 80526; 303-495-6421; or* **circle 115**; *MSTV at 800-597-3200; or* **circle 116**.

And so it goes—NOT

Those who have reviewed IBM's OS/2 Warp in glowing terms may have overlooked some installation problems. I ran into them after upgrading my home and work computers.

The beta versions of Warp installed correctly from floppies on my old ISA bus computers. But after I installed VESA Local Bus motherboards and CD ROMs, the production version of Warp would not install from CD ROM on either machine. At random points during the installation, I got the message "Device C: not available."

The problem is clearly an interaction between Warp, my Adaptec controller, my Maxtor drive, and my Texel CD ROM. Unfortunately, all three hardware vendors have denied all knowledge of Warp, leaving IBM Tech Support and me to solve the problem by ourselves. Tech Support has offered several suggestions, but so far none has eliminated the "not available" message.

Warp is a great operating system for totally brand-name computers. Whether it's also great for no-name computers with mix-and-match components has still to be determined.

Contributor John R. Hines is a silicon sensor engineer at Honeywell Inc.'s Micro Switch Division, Richardson, Texas.

Consultants: Bruce Mather, *Phototelesis Corp.*; Shari L. Pfleeger, *Systems/Software Inc.*

reflections

Surfing the net

EVERY TIME I TURN ON THE TELEVISION SET these days, I see some handsome actor in a commercial enthusing over the joys of "surfing the net." Of course, the actors look clueless, but the more troubling aspect is this sudden, overwhelming publicity for what used to be the private domain of technophiles. Perhaps it is time for me to move on to some preoccupation other than netsurfing. I am reminded of the wisdom in the old Yogi Berra quotation about the restaurant: "Nobody goes there anymore; it's too crowded."

I'm sure there are more important things for me to be doing. Get a life, as they say. There are books to read, places to travel to, and chores to do—things like that. But even in contemplating this real life, I sense an impending, ominous deprivation. I need the prickly salt wind in my face, the bubbling cushion of the sea beneath, and the powerful surge of the curling wave carrying me forward toward the very brink of stability. Oh, I need to be back at my keyboard!

I wasn't always an addict. Once I was an ordinary person, leading the clean and simple life. Occasionally I even did my duty as a citizen and watched television. I know this will be hard for younger readers to believe, but there was a time when there were only three TV channels. To change channels, you actually had to stand up and walk across the room. I didn't do that often, partly out of inertia, but also because I suffered under the delusion that you were supposed to watch the shows. I just didn't know any better.

I well remember my first remote controller, which was part of a beloved, now deceased, Heathkit TV set. A small, clever convenience, I thought. Once again the great idea swept by me unheeded. I should have heard the distant pounding of the approaching surf. I should have felt the first tremor of a sea breeze. But I held greatness in my hand and knew it not.

At first I used the remote awkwardly. Learning these skills as an adult is difficult. I would make the novice's mistake of tarrying too long on one channel. The world was a static place, and the breathtaking idea of 500 channels had yet to be conceived. Things were basically boring.

Now with Internet, the world sizzles with excitement and purpose. Who needs 500 channels when the galaxy itself beckons? The phosphors on my CRT display have a pinkish cast—due, I believe, to the red shift of the expanding informational universe just beyond the serial connection of my yearning PC. The picture on my screen has a slight jitter, no doubt because of the instability of the whole web infrastructure that envelopes the microscopic me.

After all, looking at the display on my PC is like an astronomer's looking back in time with a powerful telescope. Whatever source emitted the information currently displayed on my screen probably changed many long microseconds ago. I may well be looking at the dying light of an information dwarf. It doesn't matter; whatever this is, I won't tarry.

The World Wide Web and versions of Mosaic have elevated surfing to a new level. I'm excited about having multimedia on my PC. I show it to my computerphobic friends. "Look!" I exclaim. "It talks! It moves!"

They, however, must have a different frame of reference. They look at the small, low-resolution, quicktime movies with a frown. "You watch this stuff?" they ask.

I feel that the multimedia miracle is underappreciated. "Well, not really," I say apologetically. Anyway, I haven't time to study it. I must be on my way. I have to ride the surf back to the shore. Then I have to paddle out to sea. Then I have to ride the surf back to shore. Motion is everything. If you stop, you sink.

I show my friends the museums and galleries on-line, the exhibits from the Library of Congress, the journals and magazines experimenting with electronic publication. They seem disoriented by the long waits for access, followed by the milliseconds of observation I give to the retrieved results. But I have to move along. Nevertheless, I do have sympathy for their frustration—watching someone else steer is no fun.

I explain about the ten thousand discussion groups. "You mean *anyone* can post messages and replies?" they ask with a shade greater interest. I hate to dampen their new-found enthusiasm. But I explain that that is exactly the problem. The voices that dominate the discussion are those that choose to speak the most often, not those with the most to contribute. In any case, I shrug, it really doesn't matter in an expanding universe. Tomorrow there will be several dozen new discussion groups not yet saturated with trivia. Continuous expansion is a necessary concept in this virtual universe.

I show my friends the services and mail-order catalogs online. "How do you know where to go?" they ask.

"There is no *where* there," I try to explain.

"But how do you know which on-line stores to choose, out of so many? What differentiates one from another?"

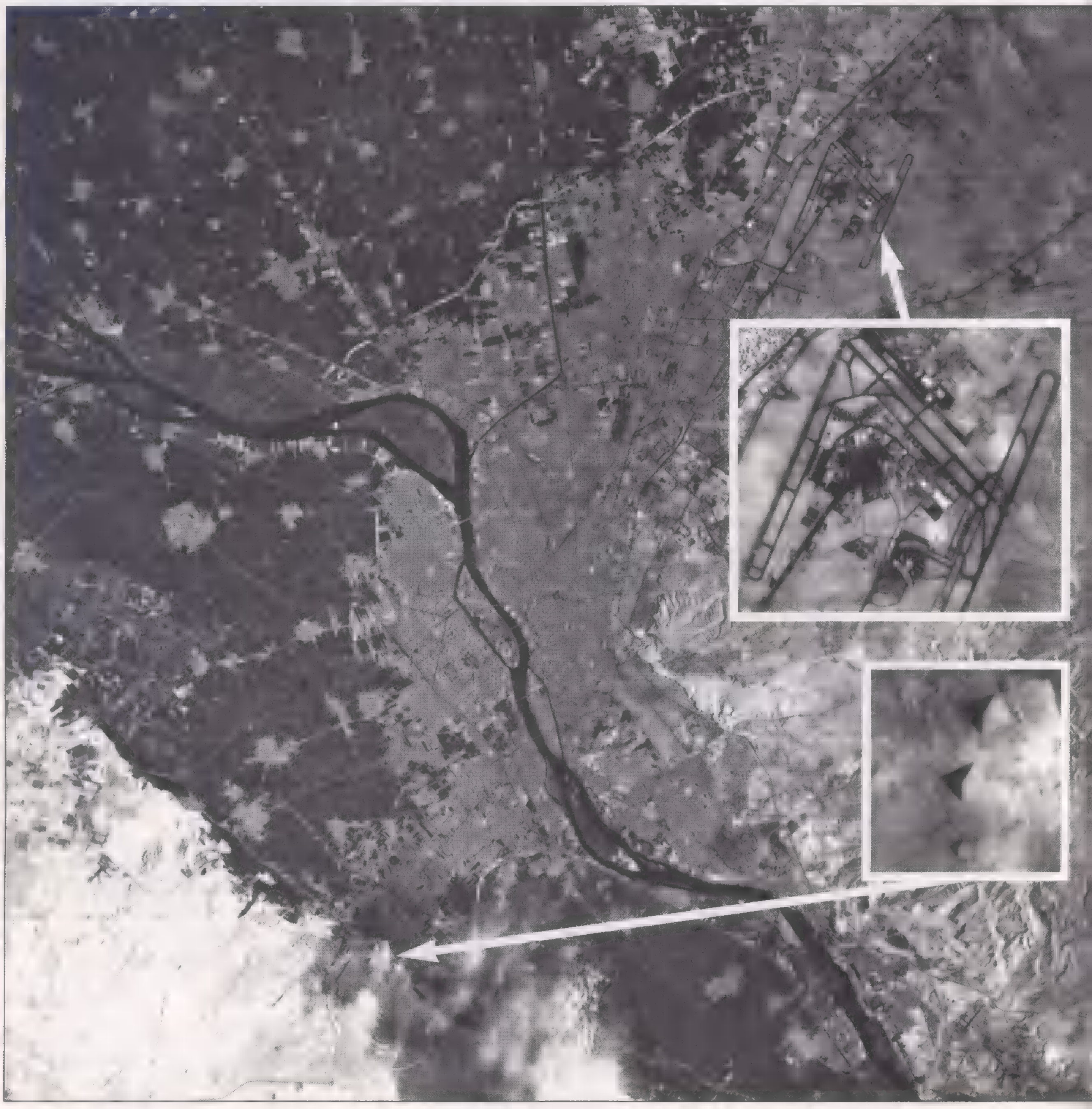
My patience is exhausted. So many questions, so few answers. Tomorrow it will be different anyway. This is a frontier society, without geographic boundaries, without laws or established customs. There is a special feel to it of exploration and freedom. And if you put your ear to the ground, you can hear the approaching hoofbeats. The settlers are coming, millions upon millions of them—and things will never be the same.

I'd like to say more about this, but I have to run. Gotta keep moving.

ROBERT W. LUCKY

special report

REMOTE



SOVINFORMSPUTNIK/EARTH OBSERVATION SATELLITE CO. (EOSAT)

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Technology for manipulating satellite imagery is now to hand—but coping with terabytes of data from future systems will up the computer ante yet again

SENSING

TRUDY E. BELL
Senior Editor

FULFILLING MORE THAN TWO DECADES OF promises, data from satellite and airborne sensors are at last being applied to all manner of earthly concerns. The delay was due not to a lack of ideas for the data's use, but to a dearth of technology users needed to bend the raw data to their will.

"Remote sensing is an *information* technology, not an aerospace technology," declared Donn C. Walklet, president and chief executive officer of TerraNova International in Los Altos, Calif. Whereas 6 MB of memory might store the information contained in a map, he noted, 200–300 MB is needed for the digital data in a single scene obtained with 30-meter resolution from the thematic mapper on one of NASA's Landsat satellites. Until now, "a lack of power and the high prices of computer hardware" necessary to process the images have inhibited potential users, Walklet said [see "Why remote sensing is an information technology," p. 26].

Within just a few years, however, two critical technologies have become both available and affordable: powerful graphics workstations for displaying the data, and affordable commercial software for manipulating them. Consequently, satellite data are in wider use than before and being mixed and massaged with greater ingenuity, too—even though some of the satellites still operating were launched in the 1980s and employ relatively old sensor technology.

With the software, maps can be generated directly from satellite data, and special-use images can be created by fusing or combining data obtained from different satellites or from nonsatellite databases. More surprisingly, subpixel analysis is extracting information about an image's content in finer detail than the image's own spatial resolution.

The result? Remote-sensing data are being used not only for monitoring climate and agriculture and discovering natural resources (as they have for years), but also for keeping tabs on payments of real estate taxes, fighting the import of illegal drugs, and for other special purposes.

Not including military and weather satellites, some 14 land-sensing satellites from diverse nations are operating in orbit around the earth; all were launched before September 1993, and seven were launched in the 1980s [see table]. Other sensors have been put into temporary orbit aboard the U.S. space shuttle, the Russian Mir space station, and similar short-lived platforms. Now high-resolution commercial remote-sensing satellites are being built.

Wavelengths at work

Regardless of their nation of origin, the long-lived satellites have general similarities. Most are in low earth orbit at altitudes of about 550 to 900 km. Most have passive multispectral sensors that look at the earth by simultaneously registering several bands of the electromagnetic spectrum—two or three bands in the visible part (usually in the red and the green and sometimes also the blue, between 0.4 and 0.7 μm), and one or more in the infrared region.

The bands in the visible and the near and mid-infrared (0.7 to 5 μm) detect the sun's radiation reflected off the earth. As this reflected light and heat is visible only during the day, most remote-sensing satellites have circular, sun-synchronous polar orbits with periods of roughly 100 minutes. In such an orbit, the satellite crosses a specific line of latitude at approximately the same local sun angle on every orbital pass; meanwhile, the earth will have turned underneath the satellite during that interval, presenting new territory to be examined.

Part of the earth's radiation, however, is emitted by earthly objects themselves because they are warmer than absolute zero. The longer wavelengths (5–1000 μm) of this thermal infrared activity can be detected in the dark, when the satellite is in the nocturnal half of each orbit. Some of the satellites observe in one or more thermal infrared bands.

Essentially, each spectral band produces only a monochrome picture of the scene. Combining the data from several bands, each in a separate (arbitrary) color, generates a multicolor image filled with all kinds of useful information, depending on which bands are utilized. Choosing an assortment of colors to reveal each object's unique spectral signature—that is, its pattern of absorbing, transmitting, or reflecting radiation from several spectral bands—can be used to classify the type and

◀ **At an altitude of 213 km above Egypt, the Russian KVR-1000 (high-resolution camera with a focal length of 1000 mm) acquired this image of part of Cairo in February 1991. Spatial resolution is about 2 meters. The panchromatic film is sensitive to visible wavelengths of 570—730 nm [green to red]. Covering 40 km by 40 km, the full photograph shows far more detail than images from civilian satellites do. A magnified section [inset at top] shows the airport with individual aircraft; the inset at bottom exposes the Giza Pyramids on the edge of the Sahara desert. Digitized KVR data is now available through the Earth Observation Satellite Co. (Eosat) in Lanham, Md., and is useful for identifying geology, water resources, land cover, and making maps for urban planning.**

health of vegetation or describe bodies of water. For example, combining the data from the visible red, green, and blue bands creates a natural-looking image that penetrates some shallow water and shows water currents, turbidity, and sediments—knowledge useful for bathymetric and coastal studies. Combining red, near-infrared, and mid-infrared data, in contrast, more clearly delineates inland lakes and streams and reveals moisture variations—useful for the analysis of soil and vegetation. In short, the process can classify surface features with high accuracy.

Visible and infrared imagery has its limitations, even so. The chief drawback is that it is blocked by clouds, haze, and rain. Enter active sensors: synthetic-aperture radar (SAR). One such system is on board the European Space Agency's ERS-1 satellite; others have been carried on the space shuttle. A SAR system beams microwave radiation toward the earth and detects the returned echoes. Radar is excellent for penetrating haze, light rain, clouds, and even some tree cover and other vegetative canopies. Although large amounts of moisture or standing water stop the return, in exceedingly dry areas such as deserts radar has actually penetrated the ground to a depth of 3 meters. It is also good at revealing topography, despite its single-band nature, which makes it difficult to classify surface features and vegetation. Last, as an active remote-sensing system, radar works as effectively at night as during the day.

Data fusion

Combining data from one sensor taken at different times or from several sensors—even from different satellites—reinforces the strengths of each type and elicits different sorts of information about the earth.

Fifteen months ago, the radar of ERS-1 pierced the cloud cover over Germany and France to record the worst flooding in Western Europe in 60 years. A merger of radar data collected on two different days highlighted changes due to flooding of the Rhône River in southern France [see figure, p. 27]. Authorities relied on the merged data gathered during and after the floods to help them set priorities for rescue, clean-up, and reconstruction.

The digital merger of radar data with the data from two or more visible and infrared bands yields the best of both worlds: sharp relief with surface classification. Similarly, it is possible to merge the multispectral data from Landsat's thematic mapper data with black-and-white photographs taken by the KVR-1000 camera on board a Russian satellite [see figure, p. 28, top] The thematic mapper's 30-meter resolution is enhanced by the 2-meter resolution of the digitized photographs.

The KVR-1000—so named for its 1000-mm focal length and the Russian words for high-resolution camera (Kamera Vysokogo Razresheniya)—was used as a reconnaissance camera by the former Soviet Union. Several times a year, the Russians launch a KVR-1000 into orbit, to circle the planet for about 45 days. It photographs about half the land surface along its ground track from a relatively low circular orbit of 220 km with a nominal inclination to the earth's equator of 65 degrees.

From that altitude, the KVR-1000 photographs have a spatial resolution of 2–3 meters, as if shot from a high-flying reconnaissance aircraft. The detail is such that in one image of the airport at Cairo, Egypt, "you can see individual aircraft," said Vicki Williams, a senior applications specialist for Earth Observation Satellite Co. (Eosat), Lanham, Md. To make the Russian images of much of the world's surface available commercially, Eosat is one of the

Why remote sensing is an information technology

So great are the demands of processing any image from on high that commercial satellite remote sensing is still far from becoming a real-time technology. Today's conversion of raw commercial satellite data into finished images takes an average of one to two weeks.

Why so long? "Remote sensing data is like raw wheat," said Donn C. Walklet, president and chief executive officer of TerraNova International in Los Altos, Calif. In his view, both commodities must undergo extensive processing to be useful, whether as imagery or as bread. Yet in the remote sensing world, "we expect the customer to pull up his or her truck to the farmer's 'grain elevator,' haul away the raw product to 'mill,' and subsequently process the raw material into some form suitable for consumption."

To sustain the metaphor, the data must not only be harvested, but also be winnowed, ground, and baked.

Most earth-resources satellites return digital data from passive sensors. Passive sensors exploit the fact that every object on earth reflects solar electromagnetic radiation or else emits its own radiation. (ERS-1, launched by the European Space Agency in 1991, returns digital data from active radar sensors that detect microwave radiation beamed to earth from the satellite itself. As for the short-lived Russian remote-sensing satellites, they return photographic film, not digital data, to earth.)

Some satellites (such as Landsat) have scanning-mirror instruments, and others (such as SPOT and IRS) have push-broom sensors. As the satellite travels north and south in its near-polar orbit, the scanning mirrors swing east and west to define a scan line, building up the basics of a two-dimensional image. The push-broom instruments, in contrast, image a complete line at a time.

Remote-sensing satellites in low earth orbit circle the planet about every 100 minutes, so the rotation of the earth below presents new terrain with each orbit. After 14 to 44 days (depending on the satellite), the starting point returns and the cycle is repeated.

Thus, in each cycle, the satellite traces out several hundred swaths (paths) running from pole to pole; each swath is divided into several hundred rows. In remote-sensing parlance, a scene is one swath/row combination; an image is one scene made on a particular date.

For both scanning and push-broom sensors, the along-track dimension of a sensor's pixels, or its instantaneous field of view, is determined by three factors: the sensor's orbital altitude, velocity, and detector integration time. The cross-track dimension is determined by the scan rate in scanners and by the detector's size in push-broom sensors. The pixels' angular size and the satellite's altitude together define the sensor's spatial resolution on the earth.

Each sensor on a remote-sensing satellite assigns several digital values to each pixel, corresponding to the measured radiation levels in its various bands. The pixel values are transmitted to earth for archiving on high-density computer tapes.

A Landsat illustration suggests just how much raw data this represents for one of the coarser-resolution remote-sensing satellites in orbit.

On each Landsat, the thematic mapper assigns seven values to every pixel—one value per measured radiation level of seven spectral bands (three visible and four infrared). As there are some 40 million pixels in every Landsat thematic-mapper scene, some 200–300 MB of data are used to represent it (each scene measures 170 km along the north-south axis by 185 km east-west).

Every two weeks, each Landsat satel-

companies that has established a facility in Moscow to digitize some 2 million original negatives collected since 1982 [see photographs on p. 24].

Hands-on mapping

One use for remote-sensing imagery is improving the type of information shown on maps. One example of software available for turning remote-sensing images into maps of cartographic quality is the Erdas Imagine system. Developed by Erdas Inc., Atlanta, Ga., Erdas Imagine can display, analyze, and combine raster and vector data from satellite images, aerial photographs, and other sources. It can also

EUROPEAN SPACE AGENCY

▶ Two radar images of the southwestern part of Provence, the Rhône River and its delta, and the Mediterranean coast were taken over a week apart and subsequently merged to highlight changes wrought by last year's flooding in Western Europe. One image from the European Space Agency's ERS-1 satellite was obtained Jan. 3 [in red], the other on Jan. 12, 1994 [in green]. A ratio of the red-to-green images is displayed in blue. Significant changes are shown in magenta, indicating heavy flooding.

lite transmits to earth 10 000 scenes or so (not every possible scene is acquired, particularly over the oceans), or nearly 3 terabytes of data. Multiply that total by two satellites and 26 cycles in a year, and the upshot is a veritable firehose of raw data.

(And this is just for the United States. Meanwhile, France, Japan, Germany, and India are being deluged with even more terabytes from their own satellites.)

If, as expected, satellite systems having 1–3 meters of spatial resolution are launched within the next few years, the firehose may grow to 1 terabyte per day.

Turning all that raw data into finished images also requires hefty computing power, not least to get rid of three categories of error.

First, the raw data contains geometric distortions that must be corrected before they can be used. The earth rotates eastward under a satellite traveling north-south while it picks up scenes of what's below. As each scene takes half a minute to acquire, the spinning earth skews the raw image from a rectangle into a rhomboid.

If a spacecraft has scanning mirrors, this skewing is compounded by vibrations within the moving parts, which cause pointing errors in the sensors' viewing angle. Further distortion comes from the nonconstant motion of scan mirrors during each scan. Because of this motion, the distances between successive pixels may vary.

Then, too, the detectors for each spectral band have different physical locations on the satellite's focal plane, giving rise to a misregistration between the bands in the raw images. And, of course, there is a geometric distortion introduced by the sensors' imaging of the earth—a three-dimensional surface—in two dimensions.

To compensate for these distortions, instruments on the satellite monitor all the possible geometric angle and vibrational errors and transmit payload correction data along with the pixel values. That data corrects the distortions in the raw image data so the pixels are properly placed on the processed image relative to their actual location on earth.

A second reason why so much computer power is needed is radiometric imbalances in the raw data. Within each spectral band measuring radiance from the earth, a satellite has not just one detector but several. On each Landsat thematic mapper, for example, each of the three visible bands and the three near- and mid-infrared bands have 16 detectors while the thermal infrared band has four detectors—a total of 100. Since no two detectors and their accompanying electronics are ever identical, each records a slightly different value.

On board the satellite, each sensor is calibrated by having its detectors record the brightness of calibration lamps after every scan. The calibration data is further analyzed back on earth to determine what gains and biases must be applied to the raw data to account for each detector's independent behavior. The goal is to ensure that all detectors use the same data number for the same input radiance.

A third call on computer power stems from atmospheric effects: unwanted energy or "noise" scattered into the sensors' field of view. The atmosphere transmits and absorbs electromagnetic energy, in the process altering it spectrally. Atmospheric scattering occurs when the direction of the energy is changed unpredictably by encounters with particles, water vapor, dust, and molecules in the atmosphere. Haze results, and images lose clarity. If desired, atmospheric effects can be corrected by the use of algorithms.

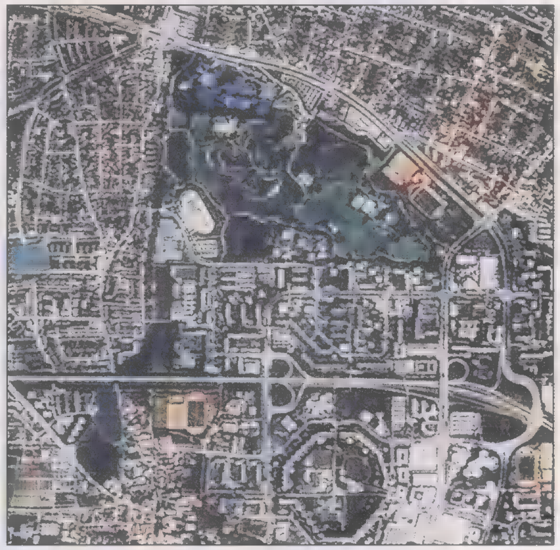
Because of the huge daily flood of data and the massive computing power required to process each image, most remote-sensing satellite data are archived in their raw form. They are seldom corrected except in response to a customer's order.

—*T.E.B.*

classify land cover, extract image features, register different types of data in one file, as well as rectify, warp, and rotate images to conform to more than 100 projections. Add-on modules allow a user to interpret and combine radar data with other imagery and to customize Erdas Imagine for specific applications. Erdas Imagine is available for DOS systems, Windows NT, and most Unix-based workstations; it is slated to be available on Windows 95 within 60 days of the software's release by Microsoft Corp.

Other PC-based systems for turning remotely sensed images into maps have also been developed. The Environment for Visualizing Images (ENVI) can be run by anyone having access to an IBM 486 DX with the Microsoft Windows NT operating system or an Apple Macintosh with System 7 or higher. The package was unveiled last year by Research Systems Inc., Boulder, Colo. Another package, EASI/PACE software for processing raster-scanned imagery, is a product of PCI Remote Sensing Corp., Richmond Hill, Ont., Canada. It can be run under Microsoft Windows 3.1 on any desktop system displaying up to 24-bit true-color imagery. Depending on configuration, image-processing software for PC systems can cost anywhere from US $2000 to $5000; that for Unix workstations ranges from $3000 to $10 000.

Such available and affordable power is firing people's imagination as to the uses to which remote-sensing data might be put. One such inspiration occurred to the Maryland State Government Geographic Information Coordinating Committee, founded in 1992. The group is using the land-classification information in Landsat imagery to update Mylar maps of Maryland's 1.8 million properties, originally based on U.S. Geological Survey maps made in 1950. The Mylar property maps are also being converted into electronic form. When the job is complete, a user will be able (among other possibilities) to click on any parcel to review its zoning and land use status and its accounts, including whether its property taxes have been paid, said John M. Morgan III, Geographic Information Systems Laboratory director and an associate professor in the department of geography and environmental planning at Towson State University in Maryland.



Part of southeast Munich is imaged in this digital merge of a Landsat thematic mapper scene with digitized black-and-white photographs by a Russian KVR-1000 camera aboard a Kosmos spacecraft. By combining the higher resolution (2 meters) of the panchromatic photography with multispectral information having 30-meter resolution, the merge facilitates the identification of surface features of use for detailed mapping. The KVR image was acquired on May 16, 1992, and the mapper image on June 29, 1992.

SOVINFORMSPUTNIK/EOSAT

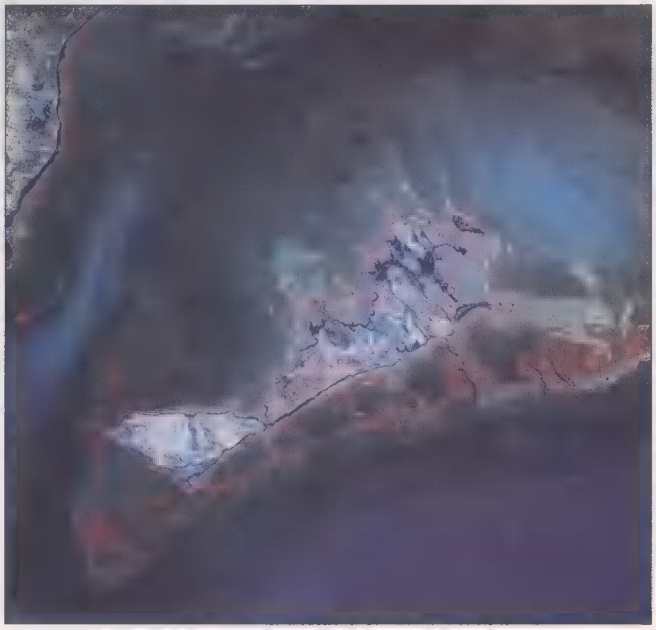
Beyond the resolution limit

The spatial resolution of just about any satellite image is larger than many of the objects of interest within the image. The pixels in a multispectral image from the French SPOT satellites, for example, are 20 meters on a side, while the pixels in a multispectral Landsat thematic mapper image are 30 meters on a side.

One way to identify objects is by their shape. But any feature (a tree, a road, a vehicle, a building, or an outcrop of rock, say) smaller than the spatial resolution will not be distinguishable as a separate entity. Another method is using the object's spectral signature—that is, the intensity of the object's spectral reflection over a range of wavelengths—as the key to identification. The spectral signature of a small feature will contribute to the overall brightness and spectral distribution of the pixel in which it appears.

Software tools are now available to facilitate the separation, or unmixing, of the spectral components that make up the overall reflectance pattern of each pixel. For example, a program from Applied Analysis Inc., Billerica, Mass., allows users to detect and classify objects that are actually smaller than the size of an image pixel.

Its inventor, Robert L. Huguenin, Applied Analysis's chief technical officer, and his president, Donald B. Damm, said the technique treats spectra of the units of interest as reference signatures. These signatures are automatically subtracted from the spectra of whole pixels so as to characterize the spectrum of the background. Next the background spectrum is subtracted from candidate pixels. Each candidate's residual spectrum is then compared with the reference signatures. If the residual spectrum agrees with the reference signature within an



EARTH SATELLITE CORP.

The underwater contours of coastal Tunisia were revealed by processing the green, red, and near-infrared spectral bands of a Landsat thematic mapper image. First, variations in water turbidity, seafloor composition, and atmospheric conditions were removed by applying a GeoView multispectral processing algorithm, which is proprietary to Earth Satellite Corp. (EarthSat), Rockville, Md. From the result, an analyst using a bathymetric chart for reference derived a depth image for the water. That image was then color-coded to mark discrete intervals in the water's depth and recombined with the land areas into the final image. Bathymetric and coastal information is crucial for such applications as exploring and developing near-shore petroleum, selecting pipeline routes, and identifying environmentally sensitive areas.

Land-resources satellites and sensors operating in low earth orbit

Satellite / Sponsor	United States	France	United States	Japan	India	Japan	Europe
Name Launch date(s)	Landsat 4, 5 1982 & '84	SPOT -1, -2, -3 1986, '90, & '93	NOAA -10, -11, -12 1986,'88, & '91	MOS -1a, -1b 1987 & '90	IRS -1A, -1B 1988 & '91	JERS-1 (=FUYO-1) 1992	ERS -1 1991
Orbit							
Altitude, km	705	632	845-861	909	904 [illegible] 900	568	785
Inclination	98.2°	98.9°	98.9°	99°	99.5°	97.7°	98.5°
Period, min	98.9	101.4	102	103	103.2	96	100
Repeat coverage, days	16	26	—	17	22	44	35
1st sensor system	Thematic mapper	Multispectral HRV[1]	AVHRR[2]	VTIR[3]	LISS[4]-I	Optical Sensor	AMI[5]
Swath width, km	185	60-80	3000	1500	148	75	[operates at 5.3 GHz in three synthetic-aperture radar modes]
Resolution, meters	30	20	1100–4000	900, 2700[c]	73	18x24	
No. of bands:							
Visible[a]	3	2	1	1	3	2	
Near/mid-/thermal IR[b]	1/2/1	1/—/—	1/1/2	—/—/3	1/—/—	2[d]/—/—	
2nd sensor system	Multispectral scanner	Panchromatic HRV[1]		MESSR[6]	LISS[4]-II	SWIR[7]	ATSR IRR[8]
Swath width, km	185	60–80	—	100	74 per camera	75	500
Resolution, meters	80	10		50	36.5	18x24	1 nadir, 1.5x2 forward
No. of bands:							
Visible[a]	2	1		2	3	—	—
Near/mid-/thermal IR[b]	2/—/—	—/—/—		2/—/—	1/—/—	—/4/—	—/2/2
3rd sensor system				MSR[9]	LISS[4]-II	SAR[10]	ATSR[7] MS[8]
Swath width, km	—	—	—	317, 317	(as above)	75	—
Resolution, meters				3200, 2300		18	—
Bands				23.8, 31.4 GHz		1.275 GHz	23.8, 36.5 GHz
4th sensor system							Radar altimeter
Band	—	—	—	—	—	—	13.8 GHz

a 0.4–0.7 µm.
b 0.7–1.5 /1.5–5.0 /5.0–12.5 µm.
c 900 meters for visible band, 2700 meters for infrared.
d One looks forward, the other straight down, to make a stereo pair.
1 High-Resolution Visible.
2 Advanced Very High Resolution Radiometer.
3 Visible and Thermal Infrared Radiometer.
4 Linear Imaging Self-Scanning Camera.
5 Active Microwave Instrument.
6 Multispectral Electronic Self-Scanning Radiometer.
7 Shortwave Infrared Radiometer.
8 Along-Track Scanning Radiometer—Infrared Radiometer/Microwave Sounder.
9 Microwave Scanning Radiometer.
10 Synthetic Aperture Radar.

Source: Earth Observation Satellite Co. (Eosat)

allowed set of tolerances, the candidate pixel is identified as containing the unit of interest.

That ability to classify subpixel-sized materials is expected to permit the mapping of individual species of vegetation. Tests have already found it about 90 percent accurate in detecting bald cypress and tupelo in test sites in the wetlands of Georgia and South Carolina [see image, p. 30, top]. According to Huguenin and Damm, the technique is sensitive enough to detect whether a pixel contains as little as 20 percent of the material of interest. The process does *not* reveal where in the pixel the unit of interest occurred; it indicates only whether the pixel contains the unit, and how much of the unit is present in the pixel. The subpixel analysis technique will be commercially available in the second quarter of this year, when it debuts as a module for the Erdas Imagine image-processing software.

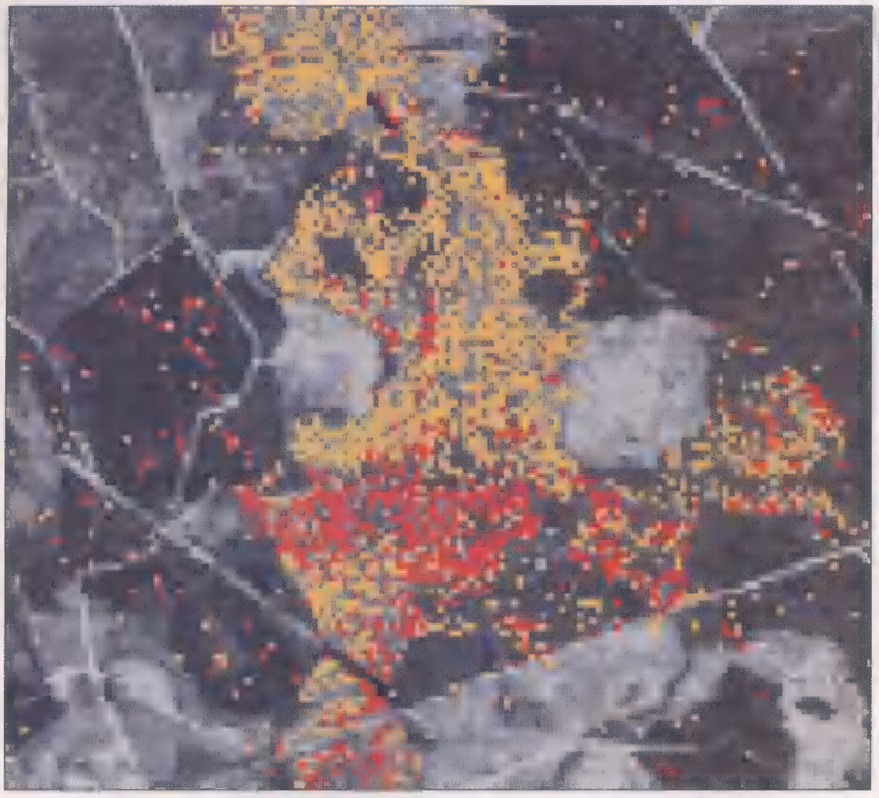
The Linear Spectral Unmixing function in ENVI is another subpixel analytical routine. For use in quantitative compositional analyses, ENVI includes spectral reference libraries of hundreds of minerals and plants, compiled by the U.S. Geological Surveys and NASA's Jet Propulsion Laboratory [see figure, p. 30, bottom].

From any viewing angle

The capacity to create two-dimensional maps from satellite imagery has been around for many years. Ascertaining the third dimension—elevation—requires a lot more computing power. In its simplest form, such topographic information can be determined by photographing terrain from two angles and combining the images stereoscopically. Now commercial photogrammetric software—such as Erdas Imagine's Orthomax—allows users to derive elevation contours for terrain from stereo-pair satellite imagery in nearly automatic fashion.

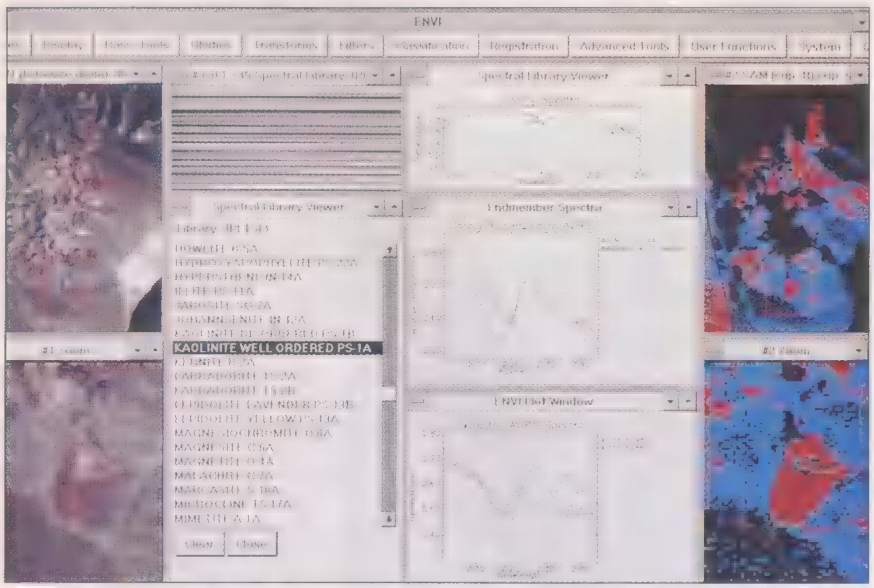
Stereo pairs may be created in three ways. One is by taking two images from one satellite on separate passes (as with the SPOT panchromatic system). A second way is to combine images from two satellites made on different passes at two viewing angles. A third way is to make two overlapping images simultaneously (as does Japan's JERS-1, which has two cameras in the same near-infrared band, one looking forward and one looking straight down).

Software also enables a user to view any terrain from any angle. That feature is offered by the Wings Mission Rehearsal interactive graphic simulation software from Autometric Inc., Alexandria, Va. Two-dimensional imagery from a Landsat, SPOT, or other remote-sensing satellite can be mathematically "draped" over a wire-frame topographic grid created from the U.S. Defense Mapping Agency's Digital Terrain Elevation Data. The result is realistic landscapes that then can be displayed from any angle, as if viewed from an aircraft flying over the land. Users also have the option of displaying the positions of fixed objects and the locations of



APPLIED ANALYSIS INC.

▲ **This image of an inland wetland near Charleston, S.C., was subjected to subpixel analysis, which reveals the presence of some objects smaller than the resolution of the image's sensor—a Landsat thematic mapper. Bald cypresses have a detectable effect on a pixel's spectral signature. A standard analytical technique counted only those pixels containing just bald cypress [red], but cypress trees were found scattered over a far larger area [yellow] by a subpixel technique proprietary to Applied Analysis Inc., Billerica, Mass. Since bald cypresses require standing water for at least part of the year, their presence means that the wetland itself was larger than depicted by the supervised minimum-distance classifier of tradition. In some of the yellow pixels, only 20 percent of the vegetation is cypress trees.**



RESEARCH SYSTEMS INC.

▲ **The presence of minerals can be revealed by subpixel analysis. A technique proprietary to Research Systems Inc., Boulder, Colo., was applied to an image of Cuprite, Nev., which had been collected by an airborne instrument called AVIRIS (Airborne Visible Infra-Red Imaging Spectrometer) from 224 visible and infrared bands. The commercial software package ENVI (Environment for Visualizing Images) for Windows revealed the presence of allunite [red] and kaolinite [blue] by comparing their spectra to reference spectra from NASA's Jet Propulsion Laboratory's Spectral Library [right].**

moving and airborne objects in real time.

One of the first military uses of Autometric's computational and display technology was in 1991, when the U.S. Marines used Wings software on a Silicon Graphics 340 VGX computer to rehearse their Desert Storm missions in the Persian Gulf. More recently, the Wings software has been used to plan relief operations for Bosnia [see image opposite].

Future sensors

Launches of the next generation of remote-sensing satellites will begin this year and are scheduled to continue into 1997. Of the first three, one is India's IRS-1C, with two bands in the visible and two in the infrared to supplement existing coverage by the Landsat and IRS satellites.

Another is Germany's MOMS-02 (Modular Optoelectronic Multispectral Scanner), schduled for launch aboard the Priroda platform on the Mir space station. MOMS-02 will return imagery (including stereo pairs) of vegetation and geological features.

The third is Canada's first remote-sensing satellite, Radarsat, which will carry synthetic-aperture radar for monitoring sea ice and other marine environments. Its resolution of 50 meters will help to support fishing, shipping, oil exploration, offshore drilling, and ocean research. The spacecraft is to be launched in August from Vandenberg Air Force Base in southern California.

Future remote-sensing satellites are being planned, some for the international Earth Observation System (EOS) to monitor the global environment. Instead of carrying multispectral instruments covering up to seven spectral bands, these will have hyperspectral instruments gathering imagery in 30 or more spectral bands.

Also planned for launch in the next year or two are compact "smallsat" commercial systems having a resolution equivalent to those of reconnaissance systems: 1–3 meters panchromatic. Several "smallsats" are being built by CTA, Eyeglass International (a joint venture of Orbital Sciences, Itek, and GDE Systems), Space Imaging (a joint venture of Lockheed and E-Systems), TRW, and WorldView Imaging in cooperation with Ball Aerospace. Meanwhile, the commercialization of former military reconnaissance data is being continued. ✚

To probe further

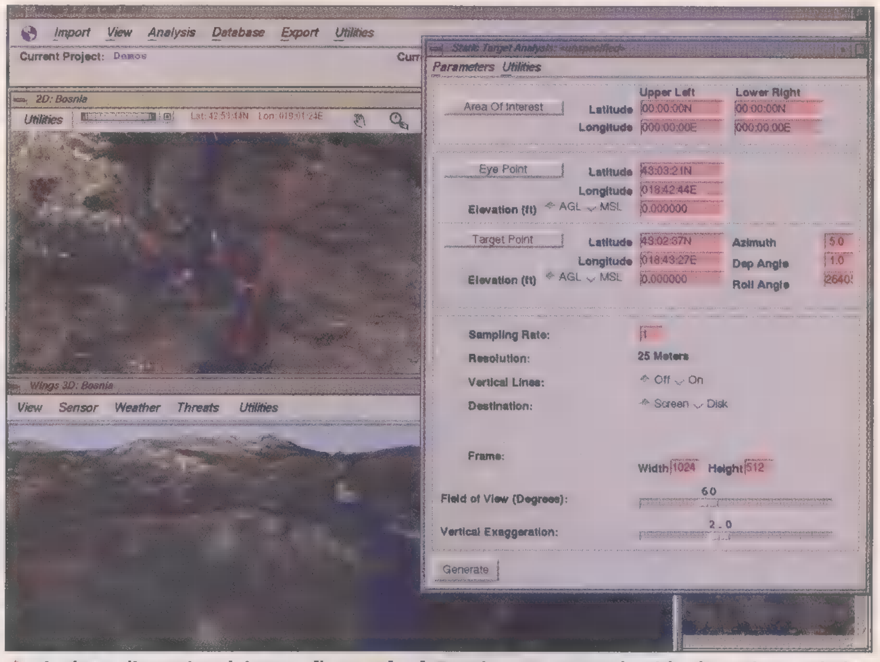
For details about satellites used to monitor changes in the climate and the environment, including the planned global Earth Observation System (EOS), see "Sensing climate change," by Glenn Zorpette, *IEEE Spectrum*, July 1993, pp. 20–27.

For a description of plans to handle the EOS's

anticipated torrent of data, see "Dealing with the data deluge," by Nahum D. Gershon and C. Grant Miller, *Spectrum*, July 1993, pp. 28–32. For a more detailed discussion of the problem, turn to *Remotely Sensed Data: Technology, Management, and Markets*, Washington, D.C. It was issued by the U.S. Congress' Office of Technology Assessment, in September 1994, as Report No. OTA-ISS-604.

A succinct overview of the currently operational remote-sensing satellites of all nations is Appendix D in *The Future of Remote Sensing From Space: Civilian Satellite Systems and Applications* by the U.S. Congress' Office of Technology Assessment, Report No. OTA-ISC-558, published in July 1993 by the U.S. Government Printing Office. To learn more on international cooperation, including the commercialization of Russian imagery, see the OTA's Report No. OTA-ISS-607 (September 1994) *Civilian Satellite Remote Sensing: A Strategic Approach*.

Offering a concise introduction to Applied Analysis Inc.'s technique is "Subpixel Analysis: Process Improves Accuracy of Multispectral Classifications." Written by Robert L. Huguenin, the article appeared in the July 1994 issue of *Earth Observation Magazine*, Vol. 3, no. 7, pp. 37–40.



AUTOMETRIC INC./EOSAT

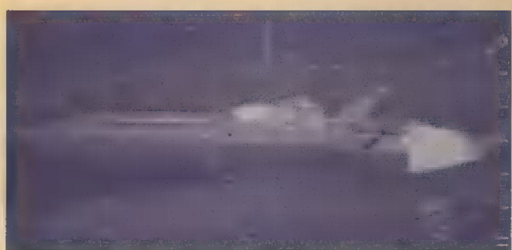
▲ **A three-dimensional image [bottom] of Bosnia was created with the Wings Mission Rehearsal software by Autometric Inc., of Alexandria, Va. The software took two-dimensional thematic mapper data from a U.S. Landsat satellite (with 30-meter resolution) [top] and mathematically "draped" it over digital terrain elevation data (with 100-meter accuracy) obtained from the U.S. Defense Mapping Agency. The purpose was to allow military pilots to simulate flying over terrain before an actual mission.**

Remote sensing versus crime

Airborne and satellite remote sensing have also played a role in combatting crime. "People dealing drugs, burglarizing homes and cars, or engaging in other criminal activity believe they are protected by cover of darkness," said Dean Queathem, vice president of marketing for the night vision systems and sensors division of FLIR Systems Inc. in Portland, Ore. "Typically, large ships will transfer their cargo of illegal drugs to small, fast speedboats that then run into coastal towns. Law enforcement officials get reports of such criminal activity, but the information is not useful if the officers can't see what's going on."

The answer? Penetrate the darkness of night by picking up an object's natural thermal infrared emissions. Any object above absolute zero emits thermal infrared radiation (heat)—hotter objects (such as fires or engine exhaust at about 500 K) at shorter wavelengths (3–5 μm) and cooler objects (such as human bodies at about 300 K) at longer wavelengths (8–14 μm).

A night vision system generally consists of a turret (an infrared sensor enclosed in an electromechanical housing or gimbal), an electronic module, a control unit, and a video display. Usually, the turret is mounted on an aircraft or ship while module, unit, and display are inside the aircraft cockpit or cabin. The electronic module is the central processing unit both for input from the control unit to the turret and for output from the turret to the video display. The infrared sensor incorporates the most critical components of the system, including a detector assembly, closed-cycle cooler, scanner optics, and electronics.



FLIR SYSTEMS INC.

FLIR Systems uses two types of infrared focal plane arrays: serial scanning and staring. In the serial scanner, a high-speed scanning mirror reflects the infrared radiation to a four-by-four array of detectors. The staring focal plane array, on the other hand, simply stares at the scene, for by integrating the radiation over a longer time than can the detectors in the scanning array, it can sense very low-intensity, ambient infrared radiation.

The serial scanner employs detectors made of mercury-cadmium-telluride; the staring focal plane array sensors are made of platinum silicide. In each case, the detectors are mounted on a dewar and cooled to 77 K.

The U.S. Customs Service has used infrared technology to apprehend so-called cigarette boats importing illegal narcotics [see photograph]. Moreover, infrared remote sensors have ferreted out sites where illegal drugs were being manufactured. "A lot of heat is involved in growing illegal drugs, particularly marijuana," which is commonly raised under grow lights, Queathem noted. Scanning houses or other structures on a cool night might reveal that a certain building is very hot or that a transformer on an adjoining power pole is hot from so much power being drawn for grow lights, he said.

Yet other law-enforcement agencies have employed remote-sensing imagery from satellites to identify the spectral signatures characteristic of coca-growing operations in South America. Coca is the plant from which cocaine is derived.

—*T.E.B.*

SLOWING THE AGING OF NUCLEAR POWER PLANTS

Maintenance of a reactor coolant system is made safer when its surfaces are periodically cleansed of radioactive oxides

STEPHEN A. TROVATO
and
JOHN O. PARRY
Consolidated Edison Co. of New York Inc.

JAMES M. BURGER
Empire State Electric Energy Research Corp.

NUCLEAR POWER PLANTS, like people, need more maintenance as they age. For us, this means additional medical checkups, nothing a doctor need fear; but for a nuclear plant, more frequent maintenance exposes the pool of workers involved to greater radiation overall.

Two other factors make a bad situation worse. Nuclear plants get "hotter" as they age, so that just when they need more care, they raise the radiation ante for those qualified to maintain them. And the latest U.S. Federal regulations have become tighter, limiting still further the permitted annual exposure of any individual to the damaging rays. The operator of an aging nuclear plant is therefore caught between conflicting obligations: to increase the maintenance of an ever hotter facility, yet keep the exposure of each worker to an unprecedentedly low level.

All done by chemistry

The solution chosen by the U. S. utility industry is chemical decontamination—more specifically, decontamination of the system that cools the nuclear reactor, namely, the full primary, or reactor coolant, system. The process is actually under way right now, about 65 km north of New York City, at the Indian Point 2 pressurized-water reactor plant of the Consolidated Edison Co. of New York Inc. It is the nation's first such application of chemical decontamination to an operating commercial nuclear power plant.

The event is being treated as a national demonstration to ensure that it benefits the entire U.S. utility industry. More broadly still, the consortium taking part is an international group of utilities and other organizations, to ensure improved technology transfer to other utilities all over the world.

The decontamination of the full primary system is being demonstrated with the fuel elements removed, during a scheduled outage for refueling. The process began last month and is due to be completed in early March. The expectation is that it will slash 80 percent from radiation field levels within the plant.

Naturally, the effort now going on has precursors. For more than two decades, research into the chemical decontamination of individual components and subsystems has been conducted by a good many organizations. Con Edison and New York's Empire State Electric Energy Research Corp. (Eseerco) did a lot, and so did the Electric Power Research Institute (EPRI). Their work established that a chemical approach can rid a variety of components and systems of much of their radioactivity without detriment to their long-term reliability.

Nevertheless, from decontaminating individual components to decontaminating a full primary system is a significant technological step. The systems affected, the technical issues to be addressed, and the logistics for undertaking chemical decontamination on such a large scale certainly confront

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the nuclear power industry with a major challenge.

In any power plant using a pressurized-water reactor, products of corrosion and wear are to be found throughout the reactor-coolant system [see drawing to right, below]. These products circulate with the primary coolant through the reactor, where some of them may become radioactive. A variety of radioisotopes are created in this manner, and for the most part, they are removed by being filtered and demineralized in the chemical and volume control system. Whatever is left over forms a metal-oxide layer on the coolant system surfaces. These extensive and inaccessible areas include the surfaces of the fuel elements, the chemical and volume control system, and the other primary support systems.

The metal-oxide layer is deposited under slightly reducing conditions, so that it shapes up as a black spinel consisting mainly of oxides of iron, chromium, and nickel but including other elements, too. Cobalt, manganese, and zinc are among those elements present in small but significant quantities. Many radioisotopes of these lesser groups are trapped in the oxide layer, sometimes as replacements for the iron, nickel, and chromium. But removal of the trapped radioisotopes is not easy, so tenaciously does the oxide layer cling to plant surfaces.

The amount of radioactive material left on the assorted surfaces is variable. It depends principally on the corrosion rates of the plant materials, the chemistry of the primary water used as coolant, and the number of sources of cobalt. In a pressurized-water reactor, the largest contribution to the radiation fields is made by two radioisotopes of cobalt—Co-58 and -60. Very little cobalt is needed to generate a lot of radiation. A single gram of Co-60 produces approximately 1100 curies of radiation activity, and 1 curie of the isotope yields a radiation field with an intensity per hour of 11 rems at a distance of 1 meter.

Now the radioactive half-life of Co-60 is 5.2 years. Consequently, even minute amounts of cobalt released into the system through corrosion can influence the running of a plant over a long period of time.

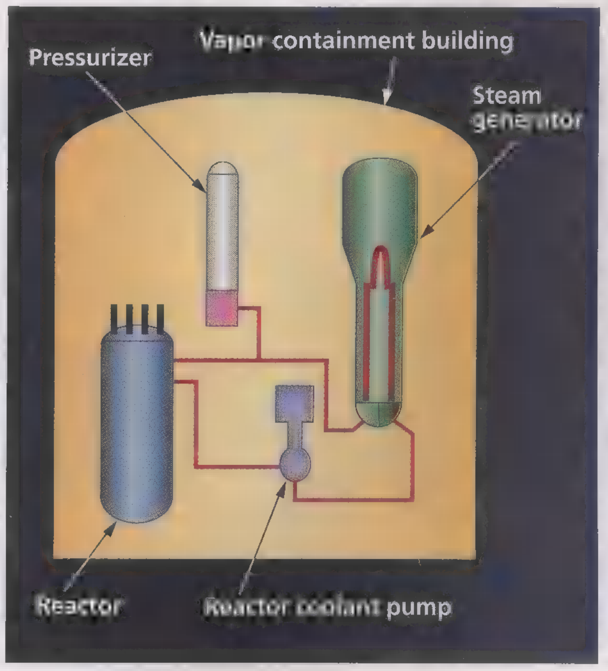
At first, after the original plant start-up, the radiation fields of the oxide layer build, but after several years they typically level off. Gamma rays are the chief component. Workers are exposed to the radiation while maintaining the plant, above all during outages for refueling, when they perform routine maintenance on major plant components, such as reactor coolant pumps and steam generators. Because a steam generator requires such extensive maintenance, it usually gives workers their largest dose of radiation—and its radiation field can be as high as *40 rems per hour*.

Why full-system clean-up

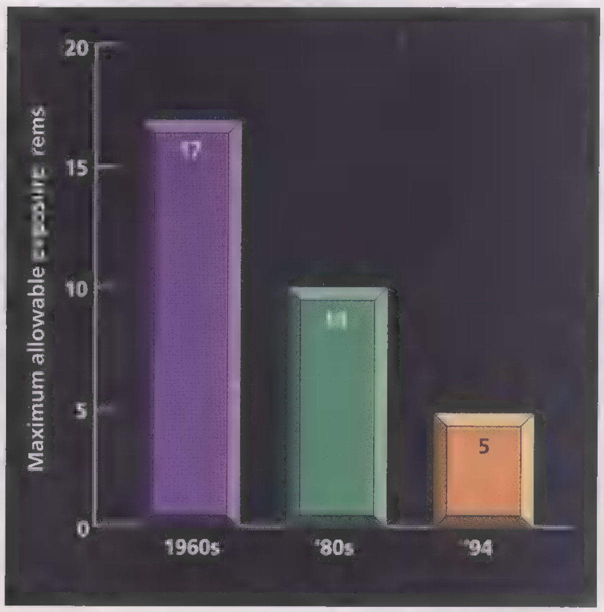
In violent contrast, the upper limit set by the latest Federal regulations is *5 rems per year* per individual. In fact, the International Committee on Radiation Protection as well as the National Council on Radiation Protection, the latter located in Washington, D.C., have recommended that no person be exposed to a total of more than 5 rems per year, from both internal sources (breathed or swallowed particles) and external. These limits are, on average, less than half the pre-1994 limits [see bar chart below].

The recommendation will affect utilities in several ways. Higher radiation doses from equipment and less exposure per worker add up to an unavailability of skilled labor once the technicians have run through their allowances. A labor shortage would be most likely to arise late in the calendar year, when annual allotments have been used up. The ruling would also leave a utility with less in the way of human resources with which to respond to emergencies.

Along with these lower exposure limits, Federal regulations were revised in 1994 to enact into law the "as low as reasonably achievable" (Alara) con-



All materials corrode and wear with time in water, even very pure reactor water. As the corrosion products circulate through the nuclear reactor, they are bombarded by neutrons, so that some become radioactive. Some of those radioactive products deposit themselves in the metal-oxide layer that forms on the interior surfaces of the full primary, or reactor coolant, system shown here.



Over the years, Federal government regulations have lowered the maximum amount of radiation to which an individual may be exposed in the course of a year. These bar figures include radiation that comes from breathed or swallowed particles as well as external sources.

cept, requiring that the exposure of personnel to radiation be minimized. The revision enables the Nuclear Regulatory Commission to set strict rules to ensure that the Alara concept is indeed realized.

Additionally, high levels of radiation reduce productivity. In a radioactive environment, more and larger crews are needed, and work is less effective. "Stay times" for crews are shorter, and set-up and clean-up times for men and materiel are much longer than they would be for the same work in a nonradioactive environment.

In other words, the component and subsystem decontaminations already performed have been of some benefit, but still greater benefits may be expected from decontaminating the full primary system. The far larger reduction in radioactivity will create a safer environment for the workers, enhance productivity, and as a result keep the cost of operating nuclear power plants competitive.

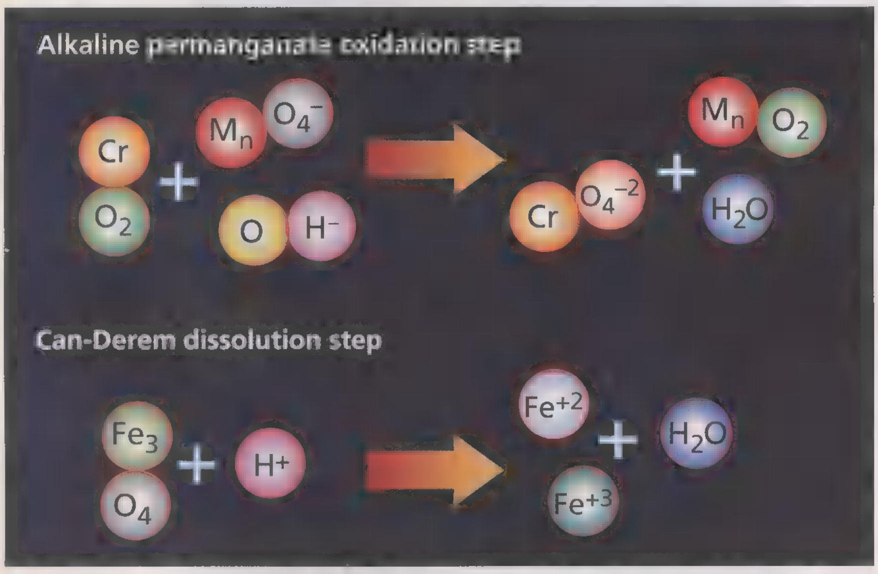
The first findings

The complex geometry and inaccessibility of the reactor coolant system preclude the use of mechanical methods of removing the radioactive oxide layer. Research has instead focused on chemical means of dissolving the layer. Once dissolved, the radioisotopes are returned to the coolant solution, from which they can be removed by filters and demineralizers.

In the mid-1970s, with the support of the U.S. Department of Energy, Con Edison began research on the cobalt-containing oxide layer on the primary system, with a view to reducing plant radiation levels by dissolving the oxide. Earlier work on chemical decontamination had targeted nuclear power plants scheduled for decommissioning, so that it did not matter what the condition of the equipment was after treatment. In the present situation, however, it is vital that a reactor's life not be shortened by the procedures used to decontaminate it.

The work on a nondestructive approach culminated in a focus on weak chemical solvents, like citric acid, which are further weakened by being used in low concentrations—less than 0.5 percent. In cleaning up plants being put out of commission, chemicals like hydrochloric acid have been used in concentrations of 1–10 percent. But because strong chemicals remove some base metal, they will not do for components that are to be returned to service. It is also hard to dispose of the kind of waste they produce.

Accordingly, in the late '70s and early '80s, Con Edison, EPRI, Eseerco, and other organizations investigated at some length the compatibility of dilute chemical solvents with the materials employed in nuclear power plants. Luck was with them. Laboratory research could prove no ill effects, nor could more than 50 decontaminations of components and subsystems carried out by the utility industry in the field.



▲ In the two-step AP/Can-Derem dilute-solvent process, chromium dioxide deposits in the oxide layer are first oxidized to less tenacious CrO_4 by an alkaline permanganate solution. Then the proprietary Can-Derem process is able to dissolve the oxide layer (containing primarily nickel and iron oxides), releasing most of the radioactive material into solution.

Two-stage attack

The early work of Eseerco and Con Edison centered on a modification of a Canadian process. A single-step reduction had been developed by Atomic Energy of Canada Ltd. (AECL) for the country's heavy-water Candu reactors. But the oxide layers in pressurized-water reactors proved to cling too firmly to surfaces to be removable in one step.

So the researchers went to a two-step process [see diagram at left]. The revised version is called the AP/Can-Derem process, where AP refers to an alkaline permanganate pretreatment and Can-Derem (pronounced candyrem) is an AECL trademark.

The oxide's high surface tenacity is due to its high chromium content. In the first step, the alkaline permanganate oxidizes the chromium from CrO_2 to the soluble CrO_4 (actually Cr^{+3} to Cr^{+6}). In the second step, the Can-Derem step dissolves the nickel and iron oxides, releasing most of the radioactive material into solution.

Con Edison has already used AP/Can-Derem on three occasions to rid Indian Point 2 of some radioactivity. The method was applied in 1989 to the regenerative heat exchanger, in 1991 to the chemical and volume control system, and in 1993 to the residual-heat removal system. This repeated decontamination has eliminated over 110 man-rems of radiation

Defining terms

Chemical and volume control system: a support system for the reactor coolant system, whose fluid flow rates it regulates in order to control water chemistry.

Pressurized-water reactor: a reactor in which the primary cooling water is kept under enough pressure to prevent it from turning into steam.

Pressurizer: a cylinder containing water and nitrogen to stabilize pressure in the reactor coolant system.

Primary auxiliary building: where support equipment for the reactor coolant system is housed, adjacent to the containment for the reactor fuel.

Reactor coolant system: the system of equipment that conveys heat from the nuclear reactor core to where it can do useful work; also called the full primary system.

Residual-heat removal system: a support system for the reactor coolant system, whose temperature it controls by means of two heat exchangers.

Spinel: one of a group of minerals with the general formula AB_2O_4, where A may be magnesium, ferrous iron, zinc, or manganese, or a combination of them, and B may be aluminum, ferric iron, or chromium.

WESTINGHOUSE ELECTRIC CORP.

This test loop constructed at Westinghouse Laboratories contains material specimens of the same alloys as the Indian Point 2 reactor coolant system. It was operated with the same chemicals and under the same conditions that would prevail later during the plant's decontamination. Examining the material specimens afterwards gave the test engineers confidence that the AP/Can-Derem process could be safely applied several times to an operating plant without compromising its integrity.

exposure, while increasing productivity and saving about $10 000 per man-rem for a total of about $1 100 000.

In 1987, Con Edison spearheaded a program to determine whether the same processes, based as they were on dilute chemical solvents, were also qualified to decontaminate the full primary system. EPRI, Eseerco, and 10 other utilities that own pressurized-water reactors also took part in the program, as did Westinghouse Electric Corp.

Two processes were picked as candidates: AP/Can-Derem and AP/Lomi (low oxidation-state metal ion). Both had been in frequent use for reducing the radioactivity of individual components but neither had been applied before to entire systems.

The processes alternate oxidation and dissolution reactions. The number and sequence of the steps depends on the assortment and concentration of chemicals to be found in the deposited oxide layer, and also on the relative effectiveness of each step. Alternating the steps is the speediest way to dissolve the metal-oxide layer.

With the AP/Can-Derem approach, a five-step procedure of three dissolutions and two oxidations has been found effective. The oxidation step is carried out at 90 °C for up to 12 hours, and the dissolution step is performed at 115 °C for up to 24 hours. The five-step total, including cleaning, occupies five outage days. It is expected to yield a decontamination factor (ratio of radiation field strength before decontamination to the strength after) of five or more.

One important question is, "For how long will the benefits of decontamination last?" Although no precise answer can be given, we estimate that significant benefits may last for as many as five operating cycles, or 10 years, at Indian Point 2. The exact length of time will, of course, depend on the rate at which the system is recontaminated.

In the AP/Can-Derem process, the decontamination solution is regenerated for reuse, with the isotopes removed by the acidic solution being captured by a cation-exchange resin. Decontamination is ended by isolating the cation resin and employing a mixture of cation and anion resins to clean up the system. The anion resin removes the chemical reagents, while the cation resin removes any vestiges of dissolved metal.

Qualifying exams

A test program was needed to qualify AP/Can-Derem and AP/Lomi for the full reactor-coolant system. But first, the conditions, parameters, and criteria for the test program itself had to be established. To this end, a detailed study was undertaken of the primary system of the pressurized-water reactor located at the Indian Point 2 plant.

An early finding of the study was that a plant system based on pressurized-water reactors can itself be used to control processes for dissolving contaminants on the full primary system. All the plant needs is the support of a temporary decontamination system for feeding in the chemicals and for receiving and processing the waste.

Another conclusion was that even although decontamination with the fuel removed from the reactor sharply reduces plant-operating costs, still sharper cost reductions would result with the fuel left in place (because the surfaces of the fuel elements would be decontaminated, too). For the first full primary system decontamination, the fuel will be removed. With experience, though, it will probably be left in place during decontamination.

Extensive surveys were conducted to compile a complete list of the materials that would be exposed to the chemical solvents. Then a series of tests was designed to address all possible issues for each material under the flow and chemistry conditions expected in the reactor-coolant system. Upwards of 250 specimens of more than 80 materials were tested.

The tests were directed by Con Edison but carried out by Westinghouse Electric. A team from the company's Nuclear and Advanced Technology Division, Pittsburgh, took samples of all the alloys in the plant. Then it built a test loop through which the same chemicals could flow at the same concentrations, temperatures, and pressures, and for the same lengths of time as would be experienced during the actual plant decontamination [see photograph above].

Tests were further performed with the chemical concentrations and temperatures raised by about 20 percent. These "fault" conditions made the tests more corrosive and demonstrated that the process had a comfortable safety margin—that is, it could safely handle unexpected excursions in conditions.

The tests were designed to establish a technical basis for decontaminating the plant at least three times during its remaining life. Engineers at Westinghouse evaluated the test results in cooperation with a utility steering committee. These evaluations were compiled, recommendations were made for application in the field, and a safety assessment was performed.

On behalf of the program sponsors, Westinghouse submitted reports on the successful qualification of the two processes to the Nuclear Regulatory Commission. That body has reviewed the reports and approved the processes' use by utilities, who will apply the technology at their sites. The review concluded that the decontamination could be performed successfully without a license amendment, and it provided certain guidelines.

Both of the candidates were approved by the Nuclear Regulatory Commission,

but application considerations persuaded Con Edison to pick AP/Can-Derem. The process offers on-line control features and cuts back on waste because of its regenerative nature. For Indian Point 2, AP/Can-Derem offered lower cost and less waste than AP/Lomi for the same relative effectiveness.

Status at Indian Point 2

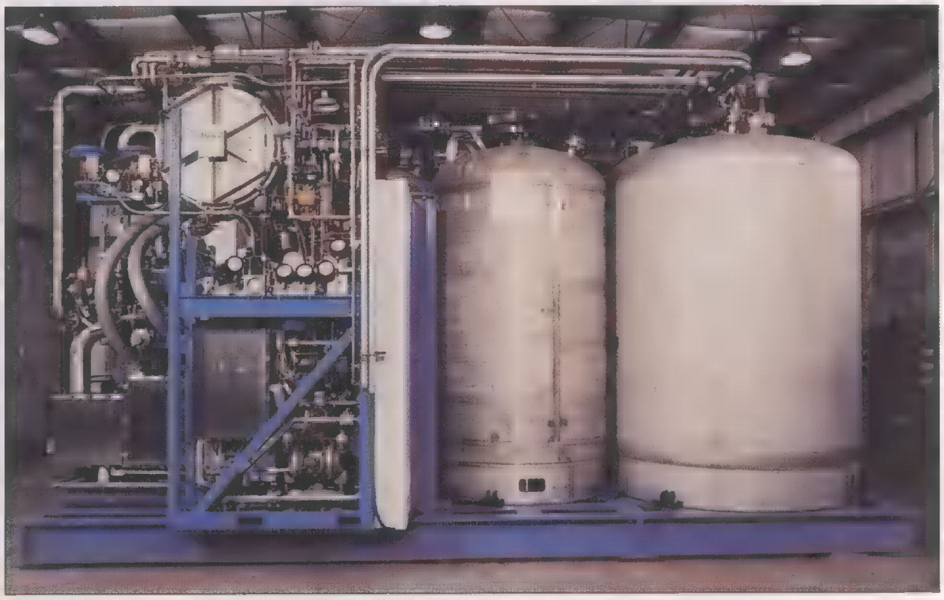
To date, things have gone well. Preparations for the decontamination of the full primary system were finished ahead of schedule. In fact, the equipment built for the project completed functional tests at the facilities of Vectra Technologies, Richland, Wash., which is in charge of the actual work of the decontamination.

By design, the system will have the smallest possible impact on the plant. Decontamination chemicals, demineralizer resins, and clean water for resin sluicing will be supplied from equipment placed outside the plant buildings. The demineralizers themselves, though, will be temporarily located inside plant buildings at Indian Point Unit 1 (which was shut down in the early '70s) in order that the radioactive material removed will be shielded. (New York State has yet to identify a final repository for the radioactive waste.) In addition, a number of minor, but temporary, modifications will have to go into effect. For example, low-pressure seals associated with the instrumentation in the reactor's core will be upgraded to cope with the higher operating pressure expected during decontamination.

Most of the in-plant decontamination system is being housed in the Indian Point 2 primary auxiliary building, in a small room that normally provides temporary storage for waste [see photo, this page]. During the clean-up process, the in-plant system will be controlled remotely from an adjoining building. That room also communicates with the plant's central control room, so that the clean-up effort can be coordinated with plant operation.

As for injecting chemicals into the primary system and removing water from it for cleansing, the means here will be the Indian Point 2 plant's system for removing residual heat. This system has been equipped with connection points for the temporary decontamination support system. From the heat removal system, solvents will travel through the reactor coolant system to the Indian Point 2 chemical and volume control system. One reactor coolant pump would suffice to circulate the solvent, but up to three may be brought on line for uniform decontamination of the reactor coolant loops.

The solvents require a certain working temperature, and the coolant pumps generate enough heat for this purpose. In the mean time, the heat removal system's heat exchangers will balance the primary system temperature. Once decontamination is complete, the resins will be pumped to containers for temporary storage on site.



VECTRA TECHNOLOGIES INC.

▲ It's a little tight, but most of the in-plant equipment needed for the decontamination process fits quite nicely into this small room in the Indian Point 2 primary auxiliary building. During actual decontamination, the process is controlled from an adjoining building.

Economic benefits

We estimate that full-system chemical decontamination could cut the costs of the utility industry as a whole by several hundred million U.S. dollars over the next 10 years. The amounts saved would vary from plant to plant, depending on age, radiation field strength, and maintenance and equipment replacement activities. At a typical pressurized-water reactor having a cycle exposure of 290 man-rems, full primary system decontamination could bring about a reduction of 200 man-rems. Further savings will flow from reductions realized in outage time, materials, and radioactive waste. (A lower-radiation environment warrants less protective equipment for workers and produces less radioactive waste.)

In the course of five operating cycles, a net savings of approximately $35 million could be achieved. In addition, if the advancement is properly publicized, the lowering of radiation levels should improve the image of the nuclear industry and make the public at large more aware of the industry's continuing pursuit of plant performance enhancements.

More immediately, participants in the on-going Indian Plant 2 demonstration will gain first-hand experience of the decontamination process and will come away from it with operating results, specifications, and safety evaluations. Consequently, they should be in an excellent position to decontaminate their plants at much lower cost.

The economics of the matter are worth stressing, as full-system decontamination can in the future be expected to become a vital part of the operation and life expectation of nuclear power plants. ●

About the authors

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John O. Parry, project manager, is a certified health physicist who has managed radiological engineering and protection groups at Con Edison and other utilities for 20 years. He is the project manager for the full primary system decontamination demonstration. He may be reached at 914-734-5038.

James M. Burger, program manager, has a doctorate in physics and manages the nuclear power program for the Empire State Electric Energy Research Corp., New York City, where he has worked for the past 19 years. His number is 212-302-1212.

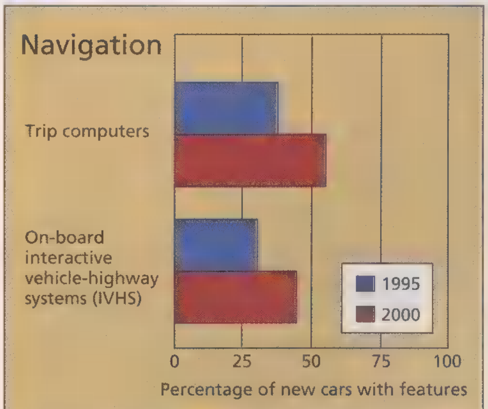
THE ELECTRONIC MOTORIST

Now is the time for novel technology—navigation gear, night vision, fuzzy logic, and more—to come to the car driver's aid

IMAGINE CROSSING THE CAR LOT LATE AT NIGHT to a welcome from your automobile: the doors unlock, the engine starts up, the heating system warms the interior to just the temperature you like. As you get in, you state your destination aloud—and the liquid-crystal display on your dashboard takes note. It lights up colorfully with, alas, the news of a water-main break downtown, but it helpfully suggests another route home.

A synthetic voice steers you along roads and across intersections through unfamiliar neighborhoods. Suddenly there's a popping sound and an indicator starts flashing, telling you your left front tire has lost pressure—you've got a flat. As you pull over to the curb, some unsavory-looking types start strolling toward you. But the push of one button sends a call for police assistance, and the push of another alerts a nearby service station to your emergency. Both calls state your exact location.

Soon, you are on your way out of town. Peering at the unlit country road, you switch on your infrared night vision system. Instantly everything is identifiable. How could you ever have managed without it?



Source: Siemens Automotive Corp. and *Ward's Auto World*

This is not a science fiction scenario set far in future, but a realistic view of the kinds of electronic capabilities ordinary cars will acquire in the next five years. And as the automotive industry gears up to make cars safer and more convenient for drivers and passengers, electronics companies stand to gain windfall profits.

In short, in the buoyant field of automotive electronics, emerging technologies should more than offset market saturation by maturing products. Revenues worldwide could reach US $15 billion in 1994, $20 billion by 2000, and $28 billion by 2005, concluded a study released in October 1994 by Siemens Automotive Corp. and *Ward's Auto World*, of Auburn and Southfield, Mich., respectively. The same study predicted that on average the cost of electronics per car would hit $1500–$1749 this year and as much as $2249 by 2000.

This *IEEE Spectrum* report focuses on some technological newcomers likely to promote strong growth in automotive electronics. The material has been culled in the main from two conferences and one book: January's Consumer Electronics Show, October's International Congress on Transportation Electronics (Convergence), and the recent *Automotive Electronics Handbook* [see To Probe Further, p. 46].

Getting there

Systems that help the driver navigate are booming. They got their start in the early 1980s, but Japan was years ahead of the West in actually getting to market, said Tsuneo Takahashi, a Honda R&D Co. engineer, speaking at the October congress.

First off the production line was Toyota Corp.'s autonomous navigation system for cars. Called Electro Multivision, it went on sale in Japan in 1987. By 1994, around 500 000 had been sold, according to the auto navigation pioneer, Robert L. French, president of Robert L. French & Associates, Fort Worth, Texas. Yet in that same year—1994—navigation systems from original-equipment manufacturers (OEM) were just being introduced to the general public in the United States and Europe.

What goes into a vehicular navigation system today? Almost all of them include dead reckoning, writes French in the *Automotive Electronics Handbook*. That is, they count wheel revolutions from a starting point and factor in turns with gyros to determine the car's position on a map. Whereas map matching is the main positioning technology, state-of-the-art systems also include a receiver for the global positioning system (GPS), now that the latter's satellite constellation is fully operational. As French points out, map matching and route guidance demand digital road maps.

Navigation systems also lean on mobile data communications for traffic and travel information in general. Essential to a typical navigation system, writes French, is a location sensor, to provide absolute position if dead

RONALD K. JURGEN
Contributing Editor

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reckoning with map matching should fail [see diagram below].

Since its 1987 launch, Toyota's Electro Multivision system has undergone many refinements. Today, using both dead reckoning and digitized maps stored on CD ROM, it displays colored icons denoting the vehicle's present position on a raster-scanned cathode-ray-tube (CRT) screen. The map database includes the whereabouts of facilities of interest to motorists. Newer versions of the system also include a GPS receiver and a color liquid-crystal display (LCD), rather than a CRT screen.

In 1991, a routing feature was added to the system, French reports. It calculates a route to specified destinations and highlights it on the LCD map. In the most recent model, synthesized-voice instructions guide the motorist along the route, and a rear-vision camera using charge-coupled devices (CCDs) produces images that are shown on the LCD screen, while the navigation features have been integrated with the car's entertainment systems.

Elsewhere, in the United States and Europe, new systems strive to differentiate themselves through price and technology. They range from stand-alone $2000-and-up systems to no-frills systems that can sell for $500 because they exploit a car's compact-disc (CD) changer and audio system.

At the low end are voice-activated systems introduced at the January Consumer Electronics Show. The basic system was developed by Amerigon Inc., Monrovia, Calif. It has no displays but uses voice recognition and synthesis in conjunction with a car's audio system. A computer module interfaces with the car's CD player, which may also have a CD changer, to read CD-ROM map discs.

A synthesized voice prompts the driver to speak the car's present location and the desired destination into a microphone. The system then analyzes the CD-ROM map, calculates the best route, and issues step-by-step synthesized-voice instructions through the car's audio system. Drivers need never take their eyes from the road. Amerigon claims that its technology, the fruit of over eight years' work, is not fazed by any of many different U.S. dialects or by foreign accents.

The new products based on Amerigon technology and introduced in January included systems from Alpine Electronics of America, Clarion Sales, Fujitsu Ten, and Kenwood USA. To describe just one, the NVA-N100 system from Alpine Electronics of America Inc., Torrance, Calif., is a $650 option for Alpine's Ai-NET audio network. It operates from a CD six-disc changer ($550), but it could be adapted to work with other changers as well.

To activate the system, the driver says "navigator" into the microphone. The CD changer then automatically selects the CD map disc. After deciding on the landmarks, addresses, or cross streets to be used as starting or destination points, the driver enters them into the system by spelling their names aloud. The synthesized voice then responds with directives, street by street and turn by turn, to the requested destination.

More established navigation systems, such as the one designed for OEM applications by Blaupunkt of Robert Bosch GmbH, Hildesheim, Germany, use displays for driver guidance. The Berlin RCM 303A mobile information center puts many controls at a driver's fingertips—those for the radio, CD changer, cassette player, telephone, and navigation system controls. A nine-button, 10-cm-diagonal LCD color monitor and integrated tuner technology are part of the package.

The driver operates the center's navigation system by selecting from a menu on the LCD screen. The system then calculates the fastest route between two locations. Unusually, the system makes no use of street maps, but shows route recommendations symbolically, on the same color screen as is used to control the car radio. An arrow indicates the best direction to take at the next intersection [see middle photo, opposite], and a computer voice informs the driver, in advance, when to make a turn. The system computes the distance to a turn and creates a shaded bar graph that dwindles as the vehicle nears the intersection where the driver should turn.

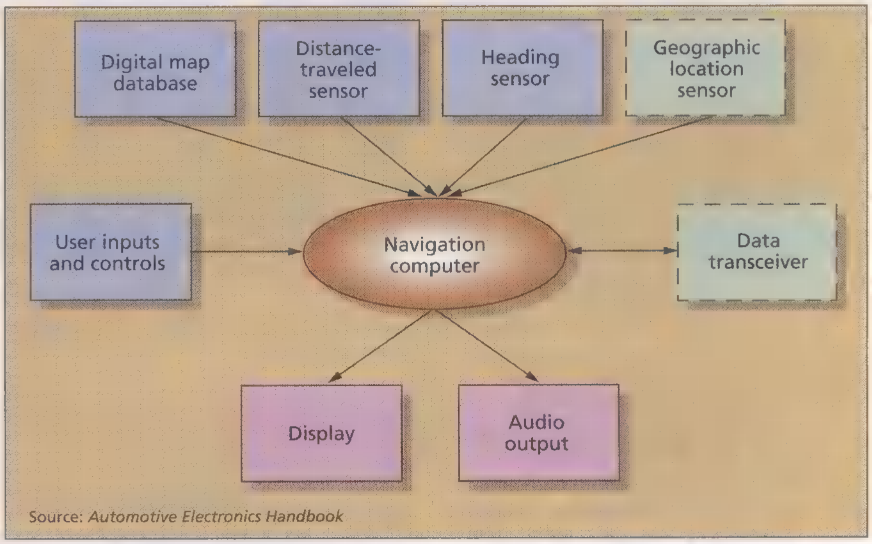
Currently, the Blaupunkt system is programmed with information covering over 650 000 km of roads in Germany alone. In the future it could be linked with a receiver for GPS signals and then could operate in other countries as well. A CD-ROM player could be loaded with data disks for the country desired.

The suggested retail price of the system, including its entertainment and navigation components, is 11 000 DM (about US $7150). The radio alone is 7000 DM ($4550). By this summer, the navigation system is expected to be available without the radio for 4000 DM ($2600).

A U.S. display-based system was tested by General Motors Corp., Detroit, Mich. For one year, ending in 1993, GM equipped 100 cars with a prototype navigation system called TravTek for an Orlando, Fla., field trial. The cars were made available either through Avis Rent A Car or by assignment to local drivers, and the American Automobile Association operated an information and services center for the test.

Travtek was a veritable tour guide: it doled out facts on navigation, route selection and guidance, real-time traffic status, local yellow pages and tourist lore, and cellular phone service. Based on dead reckoning and map matching, the experimental system superimposed vehicle location on a map display screen that highlighted suggested routes. A synthesized voice also proposed possible routes. Traffic information received by radio link from a center in Orlando was utilized to recommend the least congested routes.

A similar system is already on the U.S. market. Telepath 100, introduced by Delco Electronics, Kokomo, Ind., is a low-cost system that supplies directions to, and the decreasing distance from, selected destinations. Displaying special graphics, the system employs a GPS receiver, a dead-reckoning system for use when GPS is not available, and a map database from Etak Inc., Menlo Park, Calif. A directory gives the driver access to a listing of restaurants, hotels, and other travel destinations.



A typical vehicle navigation system comprises a wide range of electronic subsystems.

Telepath is being marketed through automobile dealers as an aftermarket product in the $800–$1000 range.

Delco said that future enhancements of Telepath 100 could include a one-touch Mayday transponder, traffic information, and way-point guidance, not to mention a head-up display for information and one-touch dialing of travel destination.

Owners of Oldsmobile 88 cars who are willing to spend rather more might consider Guidestar. This navigation-information system has been available as an option for their automobile in California since September, following a successful pilot run by Avis Rent A Car in San Jose. The system delivers accurate and immediate information and instructions from a LCD screen attached to the instrument panel [see photo, bottom right]. It was developed for Oldsmobile by Delco Electronics, Zexel USA, and Rockwell Automotive Electronics.

The system has four components. Its dash console supports seven input keys and a 6.3-by-8.2-cm active-matrix color LCD screen. Its compact GPS antenna is mounted on the rear package shelf. Its computer is mounted in the trunk. And its wire harness interconnects everything.

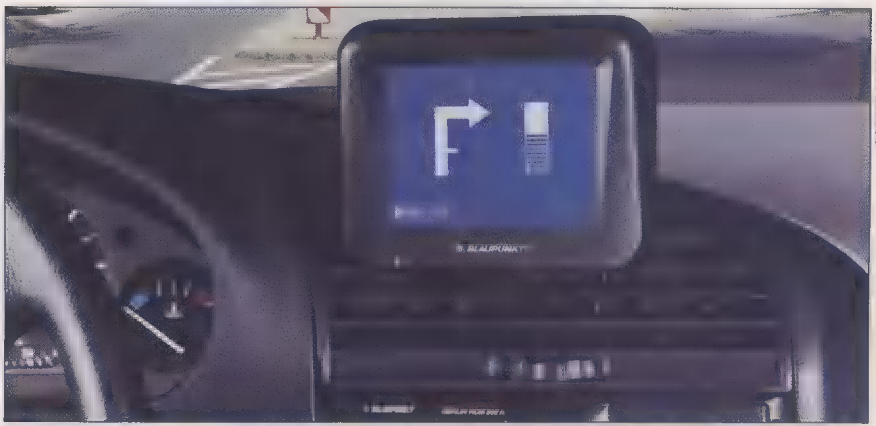
The computer monitors four channels of information. Two channels scan signals, one from the GPS antenna and the other from an internal gyroscope (to quantify cornering maneuvers). The other two check on the vehicle's speed and back-up lamp voltage (to sense direction of travel). The vehicle's location is pinpointed by advanced dead-reckoning techniques and GPS satellite inputs.

To start up the navigation-information system, the driver touches one key and is then prompted, through a menu screen, to enter details of the desired destination. Those particulars may be an address, a road intersection, a place of public interest, or even the destination of a previous journey held in the computer's memory. The system also allows the driver to select a preferred routing method, using freeways, for example, whenever possible.

Once the destination has been set, the driver guides the cursor and presses an enter key. In seconds the on-board computer, which is constantly aware of the vehicle's current location, calculates the most efficient route for the trip, and sends the LCD screen ■ map of the area highlighting the route in color. Once the trip begins, the distance to and direction of each turning maneuver is displayed on-screen in bold graphics. A voice prompt advises when a turn is approaching so that the driver's attention will not be diverted from the road. If a turn is missed or cannot be taken because of road construction or traffic congestion, the system reroutes the journey at the touch of a single key.

SONY ELECTRONICS INC.

▲ **Sony Electronics' NVX-F160 mobile navigation system utilizes the global positioning system in combination with maps on CD-ROM discs developed by Etak Inc. It also includes information from Fodor travel guides on restaurants, hotels, stores, and places of entertainment.**



ROBERT BOSCH CORP.

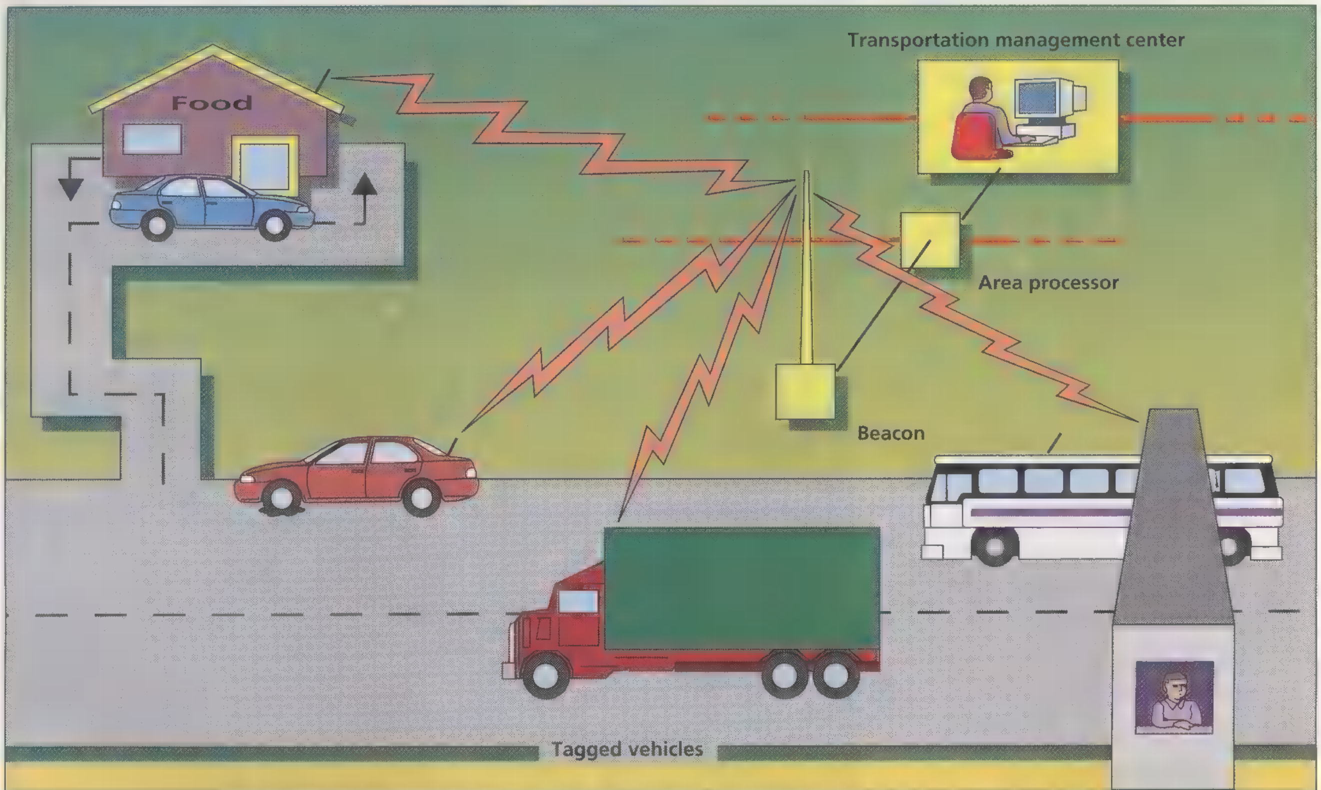
▲ **The Bosch-Blaupunkt vehicle navigation system from Germany prompts the driver with a turn signal and a bar graph that gets steadily shorter ■ the vehicle approaches ■ desired turn. A voice prompter tells the driver when the turn is near.**

OLDSMOBILE

▲ **Oldsmobile's Guidestar navigation system is mounted in the dashboard but is removable. The display shows a destination menu, routing preference, street number input, and turn-by-turn route guidance.**

The manufacturer's suggested retail price for Guidestar is $1995, including its installation and the California database cartridge that covers the Las Vegas metro area. Oldsmobile introduced the system in Michigan, Illinois, and Indiana late last fall. Mapping cartridges covering Florida and Georgia were available by the end of last year. Cartridges for the areas covering Washington, D.C., Maryland, and Virginia, and for New York, New Jersey, Rhode Island, and Connecticut will be on the market early this year. The system is scheduled to be available nationally in the first quarter of 1996.

For the aftermarket, one of Guidestar's developers, Rockwell Automotive Electronics, Troy, Mich., has introduced basical-



Intelligent transportation system (ITS) user services

Travel and transportation management

- En-route driver information
- Route guidance
- Traveler service information
- Traffic control
- Incident management
- Emissions testing and mitigation

Travel demand management

- Pre-trip travel information
- Ride matching and reservation
- Demand management and operations

Public transportation operations

- Transportation management
- En-route transit information
- Personalized public transit
- Public travel security

Electronic payment

- Payment services

Commercial vehicle operations

- Electronic clearance
- Automated roadside safety inspection
- On-board safety monitoring
- Administrative processes
- Hazardous material incident response
- Fleet management

Emergency management

- Notification and personal security
- Vehicle management

Advanced vehicle control and safety systems

- Longitudinal collision avoidance
- Lateral collision avoidance
- Intersection collision avoidance
- Vision enhancement for crash avoidance
- Safety readiness
- Pre-crash restraint deployment
- Automated highway systems

Source: ITS America

ly the same system, called PathMaster, for a $2495 suggested list price. Another developer, Zexel USA Corp., Farmington Hills, Mich., has its own version called Navmate, which it has licensed to Rockwell International and Siemens AG.

Other top-end navigation systems launched at the Consumer Electronics Show came from Sony and Pioneer. The $2995 NVX-F160 from Sony Electronics Inc., Park Ridge, N.J., uses GPS technology and an Etak map database to provide directions and detailed information illustrated with sound and photos [see top photo, p.39] It includes 5800 listings from Fodor's, a publisher of travel guides.

The $2850 GPS-X77, introduced by Pioneer Electronics USA Inc., Long Beach, Calif., stocks 120 000 information listings in 90 categories. Although similar technologically to the Sony system, the Pioneer system provides less detailed listings, but more of them.

A different approach to navigation systems has been taken by SEI Information Technology, Plymouth, Mich. Its technology, EnRoute, gives travelers information through wireless data networks. EnRoute delivers step-by-step navigation data as well as route guidance between any two points in a region. While loaded databases are installed in the car, users also have access to remote terminal query systems. The driver, for example, can use a cellular telephone to call up the remote server for real-time, updated travel information—data that can be downloaded into a laptop computer or personal digital assistant.

Smart transportation nearer

Navigation systems are just one component of intelligent transportation systems (ITS). In the United States, this ITS group so far includes advanced systems in traffic management, travel information, vehicle control, commercial vehicle operations, and public and rural transportation. Indeed, ITS is expected to create a $200 billion industry over the next 20 years, according to the Intelligent Transportation Society of America (ITS America), a nonprofit association located in Washington, D.C.

To ensure ITS flourishes, the U.S. Department of Transportation (DOT) and ITS America are working with many organizations at national and international levels. But decisions on what ITS will comprise and how it will be used will be made primarily by state, regional, and local agencies—with plenty of input from transit and commercial fleet operators, consumers, and public interest groups.

Already some of the interested parties have participated in a program-planning process. Its goal: to identify a number of capabilities or user services that, if deployed, will collectively meet ITS goals. Currently, there are 29 user services that fall into seven general areas [see block diagram, opposite].

An integrated ITS system is a key aim of the program. So DOT set up the National ITS Architecture Development Program, with a view to completion of the development by mid-1996. The architecture is to describe how system components will interact in order to meet system goals. An explanation of how the system operates will be included, as will what each component of the system does and what information is to be exchanged among the components. The structure is to be flexible enough to accommodate different levels of implementation,

Vehicle location system alternatives

Location technology	Accuracy	Coverage	Operating frequencies	Update interval	Mobile equipment cost
Global positioning system (GPS)	<100 meters	Global	1227 and 1575 MHz	1 second	US $400[a]
Mobile communication satellites	>100 meters	Variable	137 MHz to 14.5 GHz	Variable (occurs every transmission)	None (if communication terminal is already in vehicle)
Global maritime distress and safety systems (GMDSS)	10–20 or 3–5 km	Global	121, 243, and 406 MHz	Hours	$200 (10–20 km) or $1000 (3–5 km)
Argos	150 meters (with highly stable oscillators)	Global	137 and 401 MHz	Hours	Varies (Custom-built hardware)
Loran-C	<0.8 km on land	Continental United States	100 kHz	>10 seconds	$200–$400
Omega	>>1 km	Global	10.2, 11.33, and 13.6 MHz	>10 seconds	$30 000[b]
Lojack	Line of bearing available to ±11%	65-km² box, centered on Lojack-equipped police cruiser	173.75 MHz	Not applicable	$595[c]
Cellular-phone-based systems	Within a cell (46 meters at 8 km with special directional finder)	Cellular system area of coverage	824–849 MHz	Variable (occurs every transmission)	None (if cellular phone is already in vehicle)
Dead reckoning	<2% of distance traveled	Global	Not applicable	1 second	$50–$5000

[a] Price falls to $100 for the Tidget device, which samples satellite RF signals for a distant base station to use in computing vehicle location.
[b] Advent of more accurate systems has driven pure Omega systems from market; cost represents Omega hybrids (with GPS).
[c] Not modified for automated collision notification (ACN).

Source: *Proceedings, Convergence '94*

PARALLEL-VECTOR SUPERCOMPUTERS ENTER THE TERAFLOPS ERA

Now that supercomputers have comfortably settled on the GigaFLOPS plateau, the next target is TeraFLOPS – one trillion (10^{12}) floating-point operations per second. NEC has become the first to enter the TeraFLOPS era with the introduction of new parallel supercomputers.

Our SX-4 Series features a balanced, scalable, parallel-vector architecture that spans a 1,000-fold performance range from one GigaFLOPS to one TeraFLOPS. The SX4 Series includes five compact models with one to four processors (comparable to high-end UNIX computational servers); five single-node models with four to 32 processors; and six multi-node models with 16 to 512 processors.

The SX-4 Series features extraordinary price-performance. Instead of costly and high-power ECL chips, the SX-4 Series uses high-speed, low-power CPUs implemented with a 0.35-micron CMOS process. Further progress comes from the use of 4Mb synchronous SRAMs for the main memory. The use of low-power CMOS chips permits air-cooling for all models. This substantially reduces installation costs and complexities.

The first of the new supercomputers to enter service is an eight-processor, 16 GigaFLOPS model for the Atmospheric Environment Service of Canada. It is expected to deliver a fourfold increase in the accuracy of coast-to-coast weather forecasts.

DOMSAT MOBILE PHONE SERVICE IN AUSTRALIA

For countries which spread across vast territories, domestic satellites are the key to mobile telephone networks with nationwide coverage. Optus Communications of Australia started a new satellite-based mobile communications service.

Using Optus domestic satellites, the Optus MobileSat® service extends coverage across the entire Australian continent and up to 200km out to sea. Existing cellular phone networks cover only urban areas, which make up about 3% of Australia's land mass.

MobileSat provides high-quality, digital voice, facsimile and data services for people working in remote areas. Previously, HF radio was the main means of long-distance communication in such areas. MobileSat telephones consist of a handset, L-band transceiver measuring 32 x 35 x 12cm, and 96cm rod antenna.

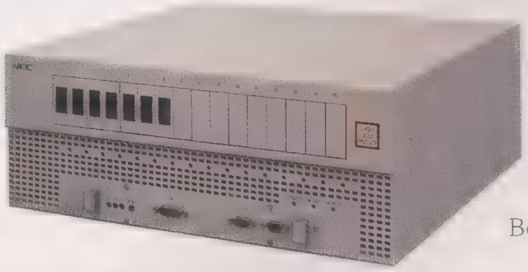
NEC Australia worked with Optus for four years on the development of the new service. NEC supplied MobileSat telephones and complete systems for the MobileSat Network Management Stations in Sydney and Perth. These two stations handle Ku-band communications links with the Optus satellites. They also provide call management, call records, and interface with the Public Switched Telephone Network.

DESKTOP ATM SWITCH FOR LANs

For users who need a broader bandwidth capable of transmitting all kinds of information – voice, video and data – workgroup LANs based on ATM technology are an ideal solution. NEC offers a high-performance, desktop ATM switch for workgroup LAN applications.

Our ATM Switch Model 5 features aggregate throughput of 2.4Gbps. It has ports for up to 16 line interfaces which accommodate ATM 100M/140M MMF, OC-3c/STM-1 (155Mbps) MMF/SMF/UTP-5, DS3 (45Mbps) and E3 (34Mbps). Each port has a 1,000-cell input buffer to minimize cell-loss caused by traffic bursts. The Model 5 supports both permanent and switched virtual connections and performs 4,096 virtual connections per interface.

The Model 5 uses an Expandable ATM Output-Buffer Modular Switch (XATOM) which is implemented in a custom-designed CMOS chip set. XATOM efficiently handles both constant-bit-rate and multicast traffic. XATOM's back-pressure control algorithm provides multi-level traffic control including congestion control, priority control and traffic shaping.



The desktop ATM switch measures 435 x 420 x 165mm. It complies with requirements by ITU-T, ANSI, Bellcore, ATM Forum and ETSI.

1Mb CMOS SYNCHRONOUS SRAMs

To perform up to their full potential, today's supercharged microprocessors need cache memories that match their blazing speed. Conventional SRAMs are too slow. BiCMOS SRAMs have the speed, but they are expensive and power-hungry.

NEC's new 1Mb CMOS SRAMs use synchronous technology with burst counters to break conventional speed limits. Our pipelined 32K x 32 device features 8ns access time. Two chips make a 66MHz-256KB cache for the Pentium™ or Power PC.™ Four chips make a 512KB cache for high-end PCs or servers. Interleaved or linear burst is pin-selectable.

NEC offers a wide choice of 1Mb Synchronous SRAMs. Pipelined devices provide access speeds of 8/10/12ns for 66/60/50MHz cache. Non-pipelined devices offer 12/13/14ns speeds for 50MHz cache. All our Synchronous SRAMs operate on 3.3V and come in 100-pin plastic TQFPs.

NEC

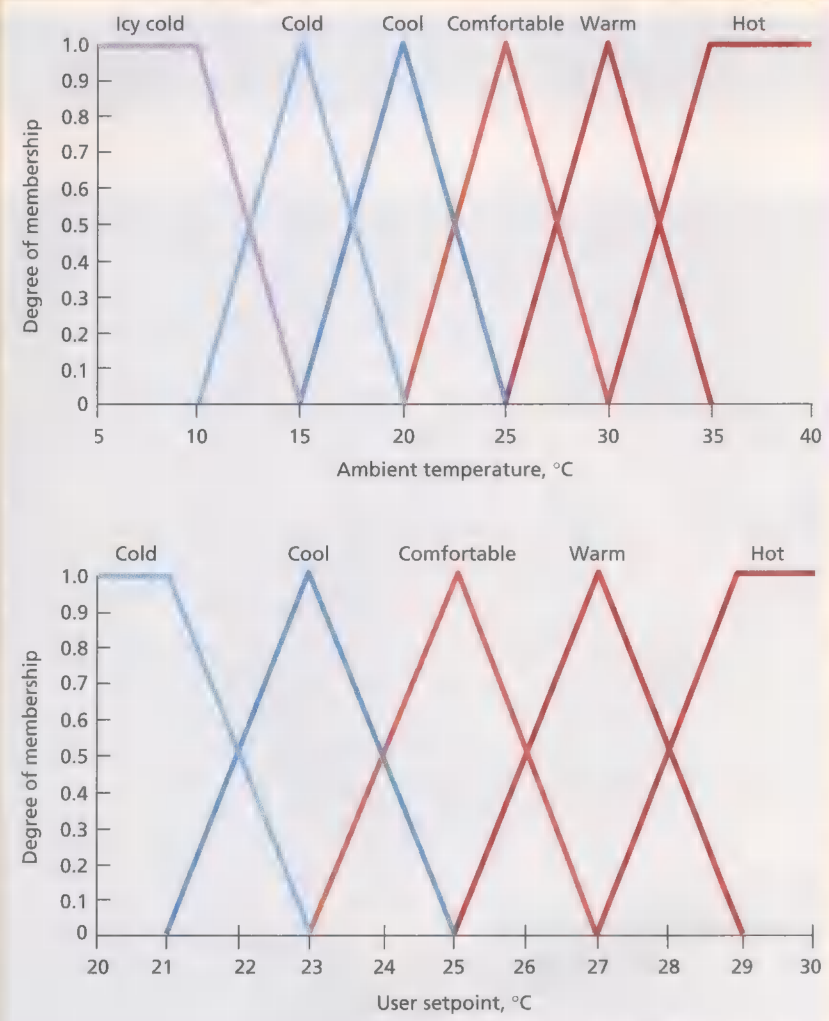
Fuzzy logic ■ the road

Expectations are that fuzzy logic will be a boon to automotive electronics. It has already had a degree of success in cruise control and automatic transmission systems. But its type of reasoning promises far wider application. Potential applications are in controls for car speed, engines, antilock brakes, and heating, ventilation, and air conditioning.

Three situations in which fuzzy logic can shine were outlined by Shinichi Sakaguchi, a Honda R&D Co. engineer, at the Convergence congress in October. One situation would arise when the system to be controlled confronts environmental conditions that are complicated and difficult to express mathematically. Another could be when the characteristics of the system change with such factors as temperature, despite the fact that the system to be controlled remains constant. A third would be the existence of multiple control objectives.

Two fuzzy-controlled automatic transmission systems—the Mitsubishi Invecs and the Honda Prosmatec Type F—served Sakaguchi as examples.

The Mitsubishi system adds fuzzy control to a conventional technique, wrapping up the driver's intentions, vehicle status, and road conditions into ■ final judgment. Based on that judgment, the system can select from a so-called flat mode (even terrain), one that climbs a curvy hill, one that climbs ■ straight hill, or one that goes downhill. A map for each mode decides on throttle opening and gear position according to vehicle speed, as is done with the usual type of automatic transmission.



Source: *Automotive Electronics Handbook*

The Honda system goes further replacing conventional techniques entirely with fuzzy control. Fuzzy rules in the IF-THEN format serve exclusively to determine gear selection. In addition to vehicle speed and throttle information, inclination and other data are used. The Fuzzy inference determines when the driver intends to decelerate.

Heating, ventilating, and air-conditioning a car is another likely fuzzy logic application, described in detail in the *Automotive Electronics Handbook*. Here, subjectivity calls the tune, explains contributor Richard J. Valentine, principal staff engineer, Motorola Semiconductor Products Sector, Phoenix, Ariz. The system designer would define the input conditions and desired output subjectively. A car's inside temperature of, for

various system designs, and system evolution over time.

This ITS alternative architecture program is proceeding in two phases. During Phase I, now completed, selected teams developed an architectural concept and made a preliminary evaluation of it. The goal of Phase II is to develop a single national consensus architecture that will allow all user services to be interrelated.

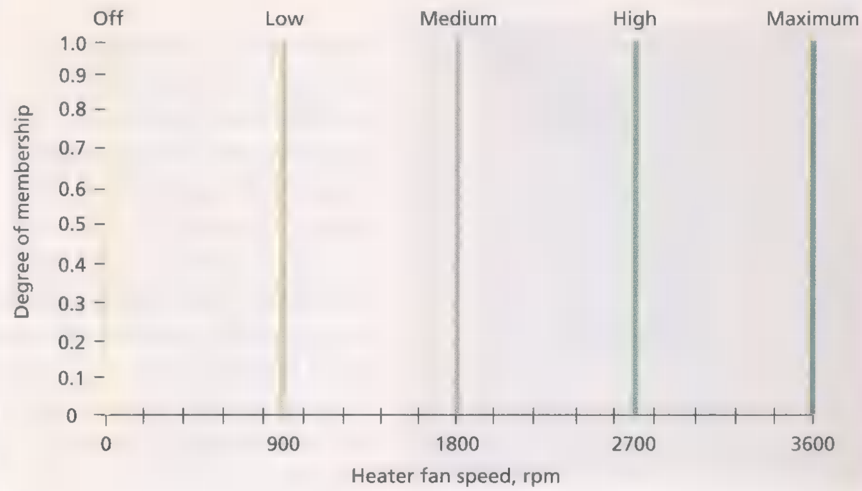
In September 1993, DOT selected four teams to develop ITS architectures based on ■ 20-year (1992–2112) implementation plan that addresses the current set of user services [see figure, p. 40]. The teams were led by Hughes Aircraft, Westinghouse Electric, Loral Federal Systems, and Rockwell International.

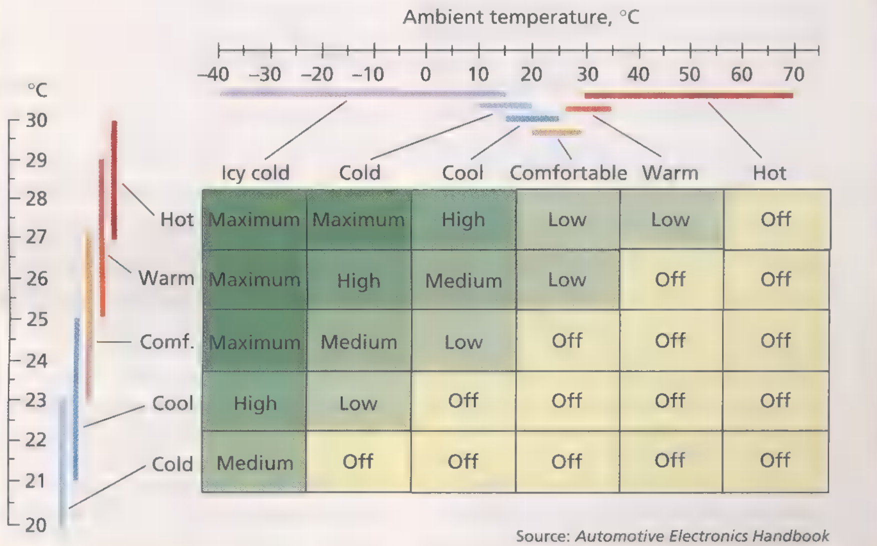
Each had its own angle on the program. The Hughes team worked on a tag/beacon approach to vehicle-roadside communications. Every vehicle was to be fitted with electronic transponder tags so that drivers might pick up on the traffic advisories provided by the system. The tags were also to give vehicles' whereabouts to traffic management centers.

Traffic advisories were to include routing around traffic snarls, road conditions and signs, and information from local business yellow pages. Travelers could also pay electronically for toll and parking fees, as well as services such as lunch at a drive-through restaurant.

Because of the use of beacon transmissions, the vehicles would have needed a cellular telephone. Another need was a route-guidance computer to figure out the best route to ■ destination and then guide its driver over that route. Planning for the trip could be handled by interactive TV in the home, at the office, and at kiosks located in hotels, bus stations, and other public areas. To warn drivers of an impending collision, radar would be used.

Others in the Hughes team were Delco Electronics, Electronic Data Systems, General Motors, Hickling, JHK & Associ-





	Icy cold	Cold	Cool	Comfortable	Warm	Hot
Hot	Maximum	Maximum	High	Low	Low	Off
Warm	Maximum	High	Medium	Low	Off	Off
Comf.	Maximum	Medium	Low	Off	Off	Off
Cool	High	Low	Off	Off	Off	Off
Cold	Medium	Off	Off	Off	Off	Off

Source: *Automotive Electronics Handbook*

example, 25 °C would feel good to most people. Translating this into fuzzy terms, 25 °C would be 100 percent true for an input membership called "comfortable," but 20 °C might be zero percent true, as might 30 °C.

Membership categories, says Valentine, could include "icy cold," "cold," "cool," "comfortable," "warm," and "hot." The ambient and user setpoint memberships are shown graphically on the opposite page. Inputs like outside temperature, humidity, and solar radiation could be added for a high-performance system.

This "fuzzifying" of the input signals is the first of the three parts of a fuzzy design. The second is to assign membership functions to the output control signals [figure at left, which shows only the heater side]. These functions are classified as singletons, which give only one value per membership.

Thirdly, the so-called min-max inference method is used to establish rules with the help of a matrix [left] representing the input and output memberships and rules. The matrix size is determined by the input membership quantity (5 for the user setpoint, 6 for the ambient temperature), yielding 30 possible rules. Then the designer selects which output membership functions should occur for each input membership function.

Valentine also tells how fuzzy logic relates to the error calculation algorithm for cruise control. Here, he notes, simple linguistics like "if speed difference is negative and small, then increase throttle slightly" are used. The throttle position update rate can also be determined by a fuzzy program that "looks for the driver's cruise performance request (slow, medium, or fast reaction), the application type (small, medium, or large engine size), and other cruise system factory preset parameters."

Other program design requirements would include: verifying the input signals were within expected limits; and testing vehicle speed to resume setpoint speed. This last would prevent, for example, too fast an acceleration to setpoint speed if the cruise resume switch should be engaged when the vehicle enters heavy traffic ("if resume and large speed error, then increase throttle slightly"). *—R.K.J.*

ates, the Michigan and Minnesota DOTs, Sprint, and the University of Minnesota.

Flexibility marked the outlook of the Westinghouse Electric team, which linked eight physical systems by a flexible communications infrastructure. Team members included Bell Atlantic Mobile Systems, Calspan, Florida DOT, Frederic R. Harris, Harris Corp., Maryland DOT, University of Florida, and Washington State University.

As for the last two approaches, "federal" architecture was used by the Loral Federal Systems team. In other words, a set of independently deployable subsystems was being designed to work together cooperatively using open interfaces. Other team members were Ameritech, Louis Berger & Associates, New Jersey Highway Authority, Oakland County Michigan Road Commission, Siemens, and the University of Michigan.

Layering distinguished the Rockwell International team's architecture. The team defined the interfaces to be developed among three complex entities, each represented as a layer. The institutional layer was to define requirements and constraints. The transportation layer was to propose solutions to those requirements and constraints. And the communications layer was to provide the means to transmit control instructions and exchange data among the layers. The other partners were Apogee Research, California PATH, California DOT, George Mason University, GTE Laboratories, Honeywell, Iowa State University, New York State and Texas DOTs, and the Texas Transportation Institute.

Phase I of the ITS program ended in late January, when DOT, after reviewing and evaluating all the approaches, selected the teams led by Loral Federal Systems and Rockwell International to continue into Phase II. They were awarded contracts for $3.7 million and $4.3 million, respectively, to perform work that will lead to a consensus national architecture by the summer of 1996. Most of the ele-

ments of a national architecture are expected to be in place by late this year or early 1996.

Engine immobilizers

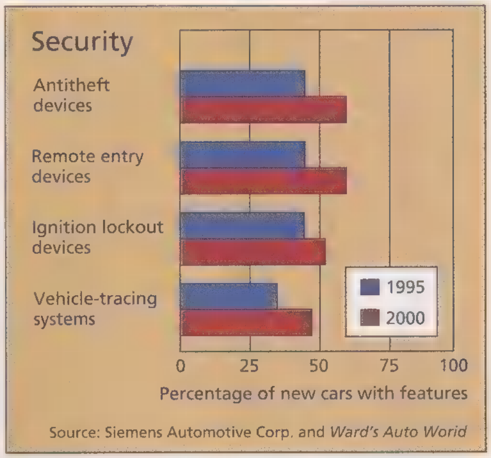
WITH CAR THEFT a plague worldwide, the pressure is on to devise deterrents that thieves will not readily circumvent. Older systems are no longer effective. In Europe, for example, the use of an in-line interrupt to disable a vehicle is being phased out since the system is too easy to hot-wire. Within the year German regulations will call for vehicle disabling that must be done electronically through the engine control module, reported Keith W. Banks, vice president of sales and marketing, TRW Transportation Electronics Division, Farmington Hills, Mich. Speaking at the Convergence meeting in October, Banks said that thieves who intercept signals from the RF transmitter to the receiver in a car, record them, and play them back later in order to steal the vehicle, can be thwarted if the system uses rolling code. This, Banks explained, changes the code each time the system is used, thereby making copied code useless.

A rolling code is usually produced by a linear feedback shift register (LFSR), according to a report at the same meeting by Alan M. Finn, Robert E. LaBarre, and Roger D. Carroll, for United Technologies Research Center, East Hartford, Conn. They described the LFSR as a counter whose operation is governed by Galois field theory mathematics and by exclusive-OR (XOR) gates. But in the LFSR, unlike an ordinary counter, the order of the numbers appears to be scrambled and hence unpredictable.

The LFSR has three parts: a shift register containing a sequence of bits (the message), a feedback register containing another bit sequence (the key), and a rule for combining the shifted bit sequence with the feedback key. In a typical LFSR, given an n-bit input message in the shift register and an n-bit feedback key at the inputs to the XOR gates, the LFSR shifts the message a single bit to the right, bringing in a 0 from the left.

If the shifted-out bit was a 1, the feedback key sends the shifted message to the XOR gates. If the shifted-out bit was not a 1, nothing happens. To ensure the message is completely mixed, these steps are repeated n times. The encrypted message is the data left in the shift register. It is this output that is retained as the next input message.

However, current vehicle immobilizers based on a rolling-code LFSR have a drawback: the LFSR output message can easily be determined by Galois field theory. Cryptographic-directed scanning, the group not-



Source: Siemens Automotive Corp. and *Ward's Auto World*

ed, can be used to eliminate likely guesses at computer speed, so that only those remaining are tried on the car. A better approach is to use two LFSRs, with one acting as the clocking mechanism to control the other. The result is a mathematical analysis that is orders of magnitude more difficult than the simple analysis for a single LFSR.

Another type of electronic immobilizer system was introduced at the Convergence congress is an advanced version by Siemens Automotive LP, Auburn Hills, Mich. Launched in Europe last year, the system is now being marketed in North America. It uses a low-frequency transponder, as well as battery power, to communicate with an on-board receiver when the motorist approaches the vehicle.

The system does more than just activate the engine controller. Because it is combined in a single unit with the RF or infrared actuators, it can unlock the doors and initiate any other desired electronic functions, such as adjusting the driver's seat, the outside mirrors, and car cabin temperature to preset positions. The smart card version of the system requires no ignition key. A multistage switch is activated as soon as the motorist is seated in the vehicle. Since the driver must be carrying the smart card, the engine cannot be turned on when the car is unattended.

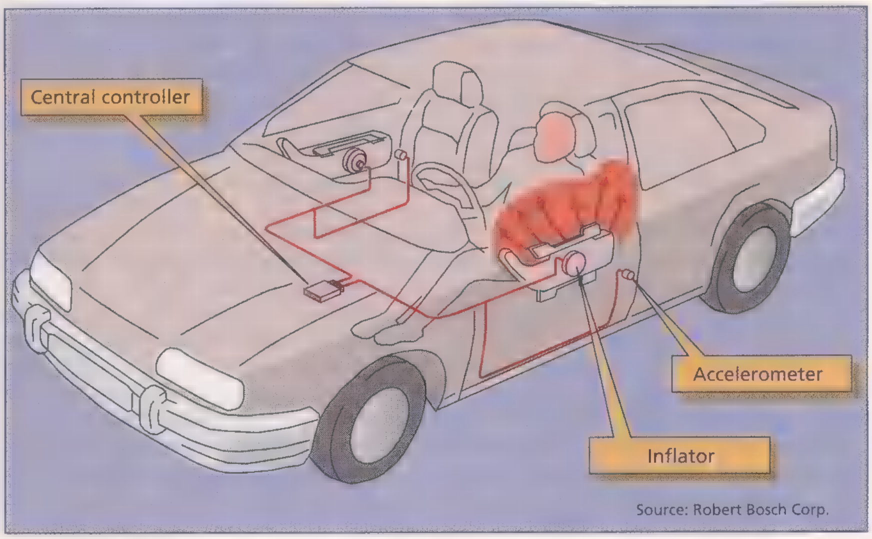
When the vehicle is taken to a service center for maintenance or repair, the card can also be used to retrieve diagnostic data and other operating information from the vehicle's engine control unit for later reference. The basic systems cost about $100 to $150.

But if a car has been stolen, despite the antitheft devices installed in it, the next best thing is to locate it quickly. One system gaining popularity for doing that is the Lojack system, which makes use of a radio broadcast system to help local authorities track a vehicle.

For $600 or so, a car dealer installs a radio transceiver somewhere in the car. At the same time, the police department is notified, and the vehicle identification number already in its computers is paired with a reply code of five letters and numbers specific to that vehicle. The police cruisers also need special equipment.

When notified of the theft of the vehicle, police officers enter its ID code into their computer. A broadcast system is alerted by this event to signal the stolen car's Lojack unit to turn on. Police cruisers within about 52 km^2 of the stolen vehicle can pick up its Lojack signal on their antenna for identification by the on-board tracking computer. The computer flashes a reply code on the cruiser's display screen, an electronic compass points to the direction to follow, while a signal-strength meter indicates the distance from the cruiser to the stolen car.

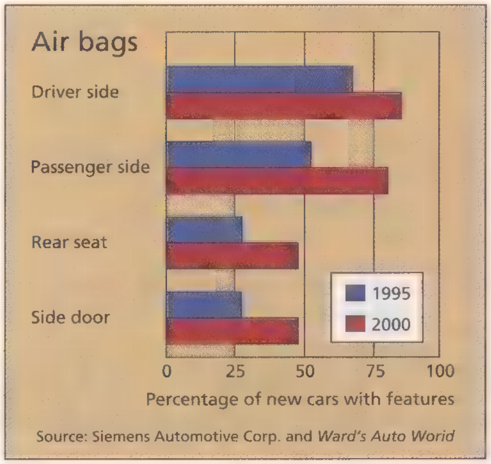
Lojack is said to allow the recovery of 95 percent of stolen cars. But it only works,



Source: Robert Bosch Corp.

▲ Side impacts affect victims sooner than frontal collisions. In the Bosch Automotive Group's system, side-mounted accelerometers trigger side air bags via a central sensing unit in 5 ms.

of course, in places where the manufacturer has donated the hardware for the system to state and local police. According to the *New York Times*, Nov. 6, 1994, Lojack is available in the Miami, Tampa, and Orlando areas of Florida; Georgia; Illinois; Massachusetts; Michigan; New Jersey; New York City and southern New York State; Rhode Island; and Virginia. Los Angeles County, Washington, D.C., and Connecticut will be the next areas to be equipped with Lojack systems. Competing systems are available, according to the *New York Times*, from Code-Alarm, Chapman, and Teletrac, with prices ranging from \$300 to \$1500 and with monthly monitoring charges from \$8 to \$15.



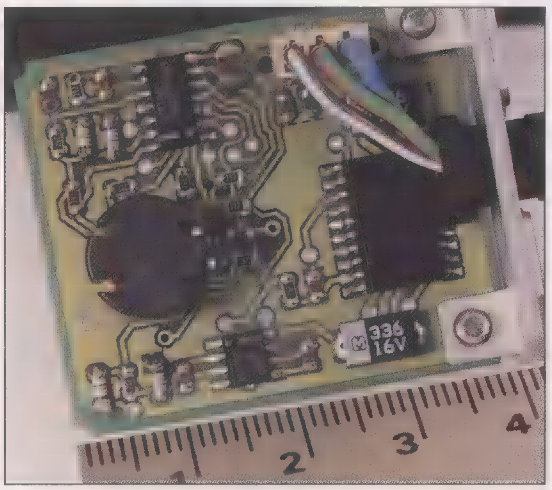
Automated collision alert

Locating a stolen vehicle quickly can mean the thieves are caught and insurance dollars saved, but there is a more pressing need for finding cars fast: to get medical personnel to an accident as soon as possible. Such a system could be available in five years, according to scientists Raymond L. Yuan, Robb W. Newman, Stanley E. Young, and Eric D. Holm from the Johns Hopkins University Applied Physics Laboratory, Baltimore, Md. At the Convergence meeting, the group described an automated collision notification system that has been identified as a critical component of the Emergency Notification and Personal Security user service (defined in the National Program Plan for the ITS).

In-vehicle equipment for this notification system, the Johns Hopkins researchers said, basically senses a crash, locates its site, and notifies a medical service. Crash sensing involves measuring changes in the vehicle's static or dynamic conditions and determining if they are due to a crash. Locating the car crash involves estimating the vehicle's position after the crash. Finally, there must be equipment to communicate the crash location to the local emergency medical service (EMS) dispatcher.

To be most effective, crash sensors, relying on vehicle deceleration and chassis deformation, should be able to distinguish between an injury-inducing crash and normal vehicle operations. Some of the technology to make that distinction is already being used in air bag systems. In other words, accelerometers or electromechanical switches that take less than 200 ms to detect large changes in a car's speed could also be applied to a notification system, according to the Johns Hopkins group. Chassis deformation detectors could be strain gauges or accelerometers placed on various locations in the vehicle.

In locating the crash site, conceivably such systems as Lojack could be used, but these systems are not available everywhere and the direction-finding equipment is restricted to police cruisers. Other technologies that could estimate where a crash vehicle has come to rest are listed in the table on p. 41, which is based on a table from the group's Convergence congress paper.



SIEMENS AUTOMOTIVE CORP.

▲ **Siemens Automotive's side-impact air-bag electronic control module features a patented absolute-pressure sensor [disc shape at left center of circuit board], which measures any change in external air pressure inside the door panel.**

Among the technologies that could help in sending the news of the crash from the vehicle to a local EMS dispatcher are those that use satellites in geosynchronous or low earth-orbit or that employ terrestrial communication systems. All these systems have earth hubs or gateway stations that could route emergency messages over the public switched telephone network (the ground stations would have to use the crash location data to identify which EMS dispatcher to alert).

A possible low-cost (under \$500) notification system was identified by the Johns Hopkins group. It uses a three-axis accelerometer integrated with an 8-bit microcontroller to sense the crash, obtain such data as change in velocity, direction of impact, and indication of rollover, and then assemble the notification message. A low– earth-orbit satellite would transmit the message and locate the crash.

Better air bag systems

Because air bags are a major means of protecting passengers in a crash, two recent trends concerning the electronics in these systems are worth noting. One is a shift toward single-point electronic sensing (and away from the conventional multiple electromechanical sensors) to reduce cost and complexity. The second is the availability of side-impact air bags to supplement bag systems that deal with frontal collisions.

Single-point systems are produced by Siemens Automotive. The company bases its system on the use of an electronic acceleration sensor that detects how much a vehicle is accelerating and then generates an electric signal. After amplification and filtering, this signal is fed to a microprocessor that evaluates the acceleration signal in real time. From the pattern of the signal, the electronic control unit determines whether the crash is severe enough to release the air bag(s) and assesses how fast to deploy it. Depending on how serious the crash is, the unit will deploy the air bag(s) in 10–20 ms after impact.

In side-impact collisions, how close occupants are to the vehicle's sides can exacerbate the harm done. Both impact sensing and air bag deployment in side-impact systems must therefore be faster than for frontal collisions. Robert Bosch Corp.'s Automotive Group, Broadview, Ill., has developed a sensor for side air bags that triggers in under 5 ms. Bosch reports that with a new gas generator, it is possible for an air bag to deploy just 10–12 ms after being triggered. The company expects the sensor to go into production in 1996.

But monitoring the minimal gap between a vehicle's interior and its occupants, according to Bosch, would require extra, outlying sensors installed near the zone of initial impact. They would have to be mounted in the vehicle's periphery (on the B-pillar or cross members under the seat). The air bags themselves could be stowed in seats, backrests, headliners, roof rails, doors, or B-pillars.

Prototype testing at Bosch to detect accelerations from side-impact collisions has shown promising results. Side-mounted accelerometers are located at the car's B-pillars, cross members, or in the doors,

where they register the impacts of large objects. A distinct increase in acceleration differentiates life-threatening side collisions from simple hammer blows and is picked up by the central evaluation electronics to which the accelerometers are connected. The central unit controls the final decision to inflate the air bags [see figure, p. 46]. To date, this single electronic control unit has reacted only to a frontal collision, by triggering the driver and passenger air bags.

Another side-impact air-bag system—or rather, control module—comes from Siemens Automotive [see photo, p.47]. A patented absolute-pressure sensor measures any change in external air pressure inside the door panel. If a hefty side impact occurs, the pressure sensor measures the blow and processes it and then, if necessary, deploys the side air bag—all in about 5–7 ms.

Bosch has also been working on an advanced side-impact detection system that would refrain from deploying an air bag for an empty passenger seat. It would also enable Bosch to exploit ■ recent ruling by the National Highway Traffic Safety Administration (NHTSA) affecting light trucks equipped with a passenger-side air bag. These vehicles are now permitted to have ■ switch mounted on the instrument panel for the driver to turn on and off by hand, to restrain or ready that air bag. Eventually, the traffic safety administration said, the switch may be replaced with an automatic detection system.

Children and air bags are a concern. The traffic safety administration has also ruled that the new rear-facing child safety seats must now have warning labels from the manufacturer, to the effect that deployment of passenger-side air bags pose risks to children seated there and that the seats should be placed instead in the car's rear seats.

Bosch's solution is a device that detects when the passenger seat is occupied.The sensor uses a capacitive measuring principle (avoiding the need for mass-sensitive sensors). The side air bag will not deploy if the seat is detected as unoccupied, even if the seat contains heavy objects or a rear-facing child safety seat.

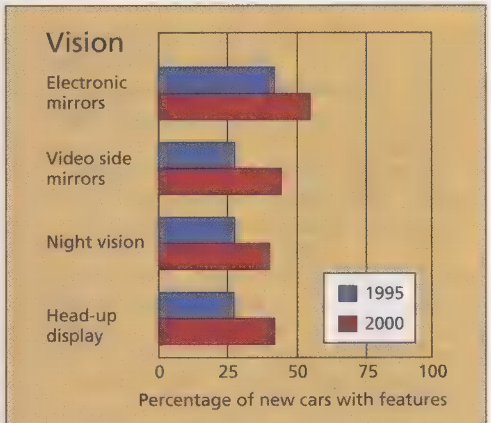
Other companies are also developing prototype systems to detect the presence of front-seat passengers or rear-facing child seats. They are using such technologies as CCD cameras and ultrasonic, infrared, capacitive, and phototonic sensors.

Flat tires flagged

Systems that warn of low tire pressure are on offer by several manufacturers . Epic Technologies Inc., Norwalk, Ohio, for example, is marketing a system that consists of four small wheel modules, one fastened to each wheel, and a radio receiver mounted in the vehicle under the dashboard.

Each module contains a 6-V lithium battery, ■ piezoresistive pressure sensor, and a 200-nW, pulse-code–modulated transmitter operating at 355 MHz. The tire pressure for each wheel is displayed on the car's driver information center panel. The center's wheel identification box blinks if the tire is underinflated.

A similar system has been demonstrated by Delco Electronics. It makes use of four small black boxes wire-banded to the wheel rim just inside each tire. Each box is a battery-powered RF transmitter that sends signals to the remote keyless entry system. When the vehicle is first started, a display on the instrument panel indicates the current condition of each tire. Pressure is constantly monitored and, when it gets too low, ■ warning light on the instrument panel goes on.



Source: Siemens Automotive Corp. and *Ward's Auto World*

The Delco system is available on the Chevrolet Corvette, provided the car is fitted with Goodyear GS-C EMT (extended mobility tires). These tires can run up to 320 km at 88 km/h at zero inflation pressure. Since they do not appear to be flat when they are without air, ■ low–tire-pressure warning system is needed to alert the driver to a loss of air. The handling, ride, and lateral stability of the run-flat tires are impressive even at zero inflation.

Driving in the dark

Night is the *bête noire* of all motorists, especially as they get on in years. But infrared equipment could help prevent accidents during the hours of darkness. The techniques are adapted from night vision technology used in Desert Storm.

Infrared cameras on the roofs of police cruisers were key in tests run in conjunction with law enforcement agencies and described at the October Convergence congress. Three companies joined forces in the effort: Hughes Aircraft, Texas Instruments, and Delco Electronics. The cameras panned across the surrounding scene and displayed the images on both active-matrix LCD panels and head-up displays inside the cruiser cabs.

The thermal imaging techniques used by the system made warm objects, like cars, people, and animals, stand out. The camera operates at wavelengths of 8–12 µm. The scene radiation is modulated by a chopper and focused by an optical imager on a two-dimensional array of infrared sensors, which convert the radiation into electric signals. The silicon IC, on which the sensors sit, amplifies the detected signals, multiplexes them, and feeds them into a single analog sampled-data signal. The signal then is digitized, an action that normalizes the responses of the individual elements, and a standard output is produced that interfaces to video monitors and recorders.

So far as the police are concerned, the system could help their work at night in chasing fleeing suspects, identifying recently driven vehicles, and previewing the road and terrain ahead. Other gains could be an efficient search and rescue, greater safety and security for the officers, and the ability to deal with a covert operation in total darkness.

Already prototypes of vehicles that include the night vision system have been developed to assess the system's value to the buyer of a passenger car. To be practical, though, costs must be brought down considerably, not only for passenger cars but for police vehicles as well. Commercial and military systems presently cost as much as $100 000 per unit.

To probe further

The *Proceedings* of the 1994 International Congress on Transportation Electronics includes the papers from the October Convergence '94 meeting held in Dearborn, Mich. Copies are available for US $88 from the IEEE (IEEE Catalog No. 94CH35729); 800-678-IEEE.

Another good source for material described in this report is the *Automotive Electronics Handbook* (McGraw-Hill, New York, 1995, $89.50). Ronald K. Jurgen, its editor-in-chief is the author of this article. To order, call 800-822-8158.

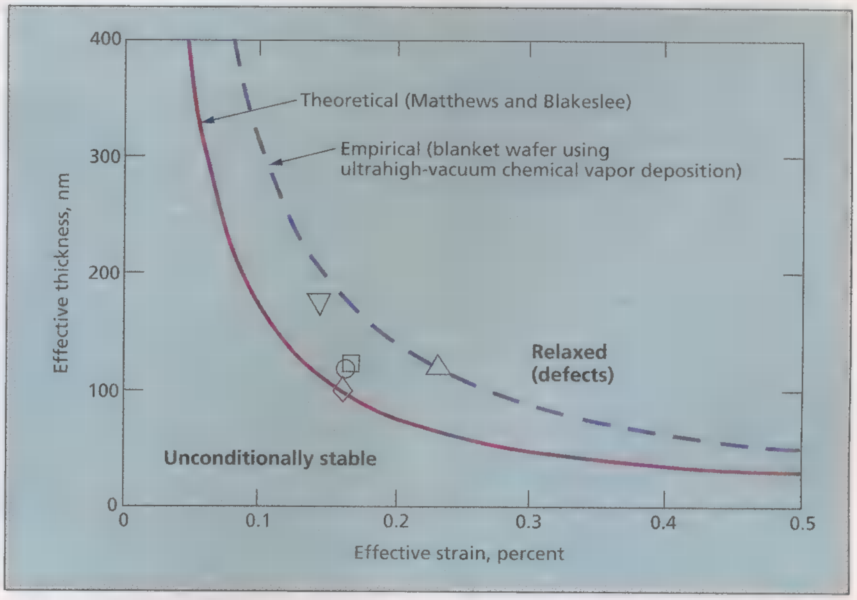
More information on the Intelligent Transportation System architecture development program is available in a summary report of Phase I, issued November 1994. For a copy, contact ITS America, 400 Virginia Ave., S.W., Suite 800, Washington, DC 20024–2730; 202-484-4847; fax, 202-484-3483. A panel session entitled "Progress in Developing ITS Architecture," will take place on March 16 during ITS America's annual meeting, Washington, D.C., March 15–17.

A few germanium atoms in just the right places lift silicon ICs to III-V performance heights without sending prices through the roof

RE-ENGINEERING SILICON: Si-Ge heterojunction bipolar technology

THE STRONG POINTS of compound and single-element semiconductors are united in a new type of transistor. A chip designer's dream, the device is the offshoot of unlikely partners: the bandgap engineering that enhances III-V compound semiconductors, and the manufacturing economies of silicon. Yet the development also harks back to those long-distant days when germanium was king—a reign that lasted from the first working transistors until its dethronement by the less costly silicon in the 1960s.

Within the past decade, techniques for growing crystalline materials have advanced to the point where germanium can be selectively introduced into silicon. When germanium is used to dope the base region of a silicon bipolar transistor, which in other respects is quite conventional, the result is a silicon-germanium heterojunction bipolar transistor. Further, the new device's properties may be tailored tightly to the needs of a desired application, because the profile and concentration of the germanium can be controlled with great accuracy. Hence the IC designer's new-found ability to devise high-speed, low-cost chips.



▲ The stability of a silicon-germanium alloy on a silicon substrate depends both on the film's thickness and on the amount of strain created by adding germanium. The greater the strain, the thinner the film must be to remain stable. A film whose thickness and strain are below the theoretical Matthews-Blakeslee stability limit [solid curve] are thermodynamically stable. Those above it are metastable, and will relax to the smaller silicon lattice constant under high-temperature processing, generating defects. An empirical stability curve [dashed line] was derived for SiGe films deposited by the ultrahigh vacuum/chemical vapor deposition technique on bare silicon wafers that were subsequently annealed. Data points are from actual SiGe profiles of a variety of experimental SiGe heterostructure bipolar transistors (HBTs).

The evolution of SiGe technology has been rapid. It has gone from a mere laboratory curiosity less than seven years ago to a commercial reality today. Currently, aggressively designed SiGe transistors have cutoff frequencies in excess of 100 GHz—an achievement that puts them in the same league with III-V semiconductor devices and ahead of the best silicon transistors by a factor of more than two.

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In fact, the technology may even help shape the development of the information superhighway. For one thing, very speedy converters can be built with SiGe, as record-breaking medium-scale ICs show. An example is a 12-bit digital-to-analog converter that processes data at 1.0 gigasample per second. Recent work also suggests SiGe could offer low-cost, high-speed radio-frequency and microwave ICs to the booming market in wireless communications.

Coming to the aid of silicon

What led to this esoteric development? Silicon is by far the most widely used semiconductor material and is likely to remain so for the foreseeable future. The element is abun-

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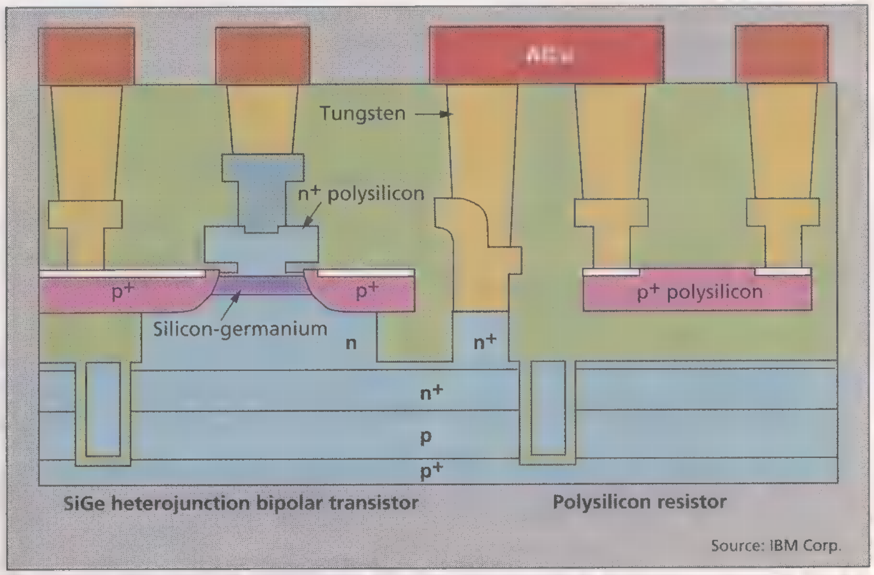
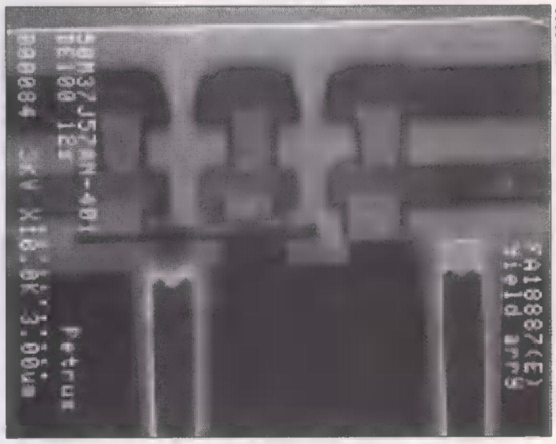
Defining terms

Chemical vapor deposition (CVD): the deposition of a chemical species from a gaseous mixture (for example, silicon from silane = SiH_4).
Cutoff frequency (f_T): frequency at which the transistor small-signal current gain is unity.
Early voltage (V_A): a measure of the change in base charge (and hence in collector current) with respect to changes in the base-collector bias.
Heterojunction: a pn junction formed between two semiconductors of differing bandgap (for example, n-type silicon and p-type SiGe).
Maximum oscillation frequency (f_{max}): frequency at which the transistor small-signal power gain is unity.
Mole fraction: the ratio of the number of moles of a substance in a mixture or solution to the total number of moles of all the components.
Ring oscillator: a series connection of logic gates with an odd number of signal transitions; it can be used to measure the average switching delay of the logic gate.
Strained-layer epitaxy: growth of a crystal of one lattice constant on a second crystal of differing lattice constant in such a manner that the two materials adopt a common lattice constant while maintaining perfect crystallinity across the growth interface. To accomplish this, the composite film undergoes strain.



In this advanced self-aligned SiGe IC, each heterojunction transistor is isolated by 1.0-µm–wide trenches etched 4.0–5.0 µm into the silicon substrate and refilled with a composite of polysilicon and oxide. Isolating the wafer surface is an oxide deposited in shallow trenches etched 0.5 µm deep and then smoothed by chemical-mechanical polishing. Heavily doped n+ and p+ polysilicon layers form the contacts to the emitter and base regions, respectively. A tungsten layer interconnects devices locally, and planarized aluminum-copper is used for circuit wiring.



IBM CORP.

This scanning electron micrograph of the cross section of a state-of-the-art SiGe HBT delineates the transistor's various layers. The SiGe layer is impossible to distinguish from the silicon substrate.

dant, nontoxic, strong, and an excellent conductor of heat. It can be grown into ultra-pure, very large-diameter crystals and readily forms a stable insulating oxide of high quality. Properties of this kind make silicon a natural for IC manufacture, and in fact, over the past 30 years or so, the performance of silicon ICs and the density of devices per unit area have soared, even as the cost per function has plunged. These exponential trends have no precedent in economic history and are in large measure responsible for the Information Age.

Yet from a transistor designer's perspective, silicon is hardly the perfect semiconductor. Compared with some of the others, it is quite poor in terms of how fast charge carriers can move through the crystal lattice. This sluggishness limits the speed at which silicon devices can operate. Nor can the element easily be made to emit or absorb light in useful quantities.

Far higher charge-carrier mobilities and saturation velocities, as well as a great capacity for producing light, are to be found in III-V compound semiconductor materials, such as gallium arsenide, aluminum gallium arsenide, and indium phosphide. Almost endless variations on their chemical composition are also possible. Adjustments of the amount of aluminum in AlGaAs, for instance, will tune the material's energy bandgap to the transistor designer's needs. Bandgap engineering, in fact, is a powerful tool for creating faster transistors, realizing a host of novel electronic devices, and achieving eminently practical goals such as designing a light-emitting or a laser diode to emit light at a specific wavelength [see "Quantum-tailored solid-state devices," by T.J. Drummond, P.L. Gourley, and T.E. Zipperian, *IEEE Spectrum*, June 1988, pp. 33–37].

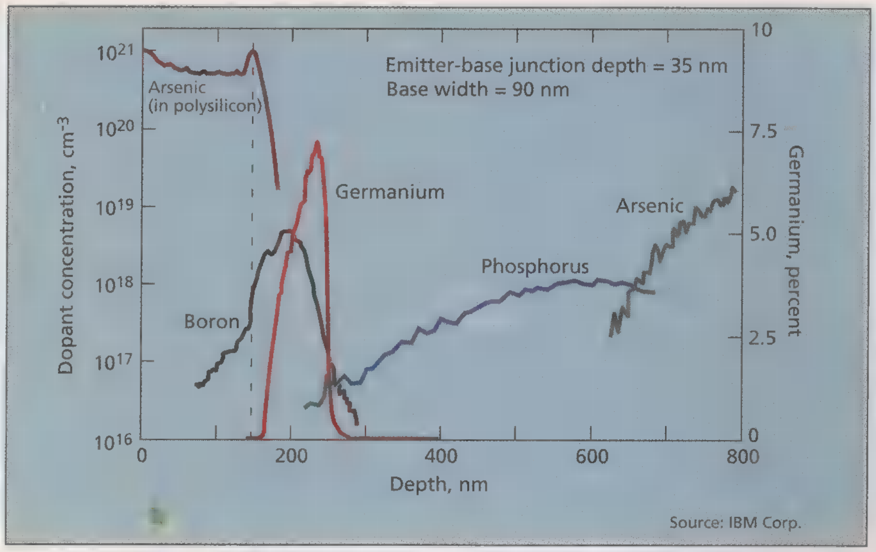
So why is silicon still dominant? The answer is economics. ICs are simply much more difficult and very much more expensive to fabricate from III-V compounds. High-quality oxides are scarce in the III-V world, impeding device integration; high-purity, large-diameter crystals are difficult to grow; and chip yields are far lower because there are many more defects to the cubic centimeter.

The dream, then, of transistor designers has been to practice bandgap engineering in silicon. The SiGe heterojunction bipolar transistor (HBT) is the first practical bandgap-engineered silicon device.

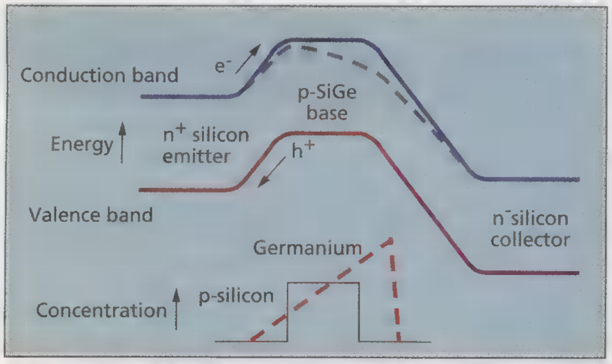
Early showstoppers

Silicon and germanium, being chemically compatible elements, can be intermixed to form a stable alloy (Si_xGe_{1-x}, where x represents the mole fraction, and is usually written SiGe for simplicity). But the lattice constant of silicon is about 4 percent smaller than for germanium, leading to a number of practical difficulties in the use of SiGe alloys in semiconductor electronics. One immediate concern is the effect of strained-layer epitaxy.

When bandgap engineering is used to construct a transistor, a perfect crystalline structure is essential, since any defects generated can devastate circuit yields. But the growth of perfect epitaxial films from alloys



The impurity doping profile as a function of depth for an advanced SiGe HBT is obtained from secondary ion mass spectroscopy. The vertical dashed line denotes the silicon surface. Arsenic from a polysilicon diffusion source forms the n^+ emitter, boron the p^+ base, and phosphorus the n^- collector. Germanium is co-deposited with the boron-doped base to produce a p-type SiGe base, and is compositionally graded from the emitter to the collector to introduce a drift field for minority carriers (electrons). The width of the base is approximately 60 nm, and the transistor has a measured peak cutoff frequency of 60 GHz.



Comparison of energy band diagrams of a SiGe HBT and a silicon bipolar junction transistor elucidates differences in their properties. Both transistors are biased identically in forward-active mode. The potential barrier to electron injection from emitter to base is lower in the SiGe than in the silicon device since there is a measurable amount of the smaller-bandgap germanium at the emitter-base heterojunction. This leads to an (exponentially) enhanced current gain for a fixed emitter-base bias. The grading of the germanium across the base introduces a position-dependent conduction band edge. The resulting drift-field aids minority carrier (electron) transport from emitter to collector, increasing the cutoff frequency.

such as SiGe is hampered by their inherent lattice mismatch. While being grown on a silicon substrate, a SiGe film can remain a perfect crystal only by adopting the smaller lattice constant of the host material. This accommodation, known as strained-layer epitaxy, induces compressive strain in the overlying film.

As is well known, strained-layer epitaxy is thermodynamically stable only under a narrow range of conditions dependent on the film's effective strain (percent germanium) and thickness. The critical thickness below which the grown film is unconditionally stable depends reciprocally on the effective strain of the layer [see figure, p. 49]. Consequently, films with high germanium content must be grown very thin if they are to be stable.

Exceeding the stability limit of a film can be dangerous. The film is then thermodynamically metastable: in other words, if exposed to more than the original growth temperature (typically 500 °C or so), or if stressed further by routine fabrication steps such as ion implantation or rapid thermal annealing, it will spontaneously relax. The relaxation generates defects, transforming the perfectly crystalline SiGe strained layer into a useless amalgam just like a shattered windshield. This no-man's land of strained-layer epitaxy is obviously to be avoided.

Growing SiGe films

To grapple with the difficulties of growing SiGe alloys, molecular beam epitaxy was used alone at first to produce thin, device-quality films. Pioneering studies in the mid-'80s at AT&T Bell Laboratories, Murray Hill, N.J., the IBM Thomas J. Watson Research Center, Yorktown Heights, N.Y., and the Daimler-Benz Research Laboratories, Ulm, Germany, among others, used molecular beam epitaxy to show that SiGe alloys could be bandgap-engineered controllably and successfully used to realize a host of novel electronic and photonic devices. The door to bandgap-engineering in silicon had begun to open.

The issue quickly became how to transfer SiGe technology from the simple device demonstrations in the research laboratory to the practical manufacture of high-volume, low-cost SiGe ICs—a task for which molecular beam epitaxy by itself is unsuited. The kind of SiGe transistors that can be built with the technique is limited to mesa devices (so named because the devices are isolated from one another by etching back deposited layers to form a mesa, rather than by using a conventional field oxide). Although mesa-type devices are useful for studies of transistor physics, they cannot easily be integrated into circuits.

However, by 1986 a key step had been taken toward commercializing SiGe technology—the development of ultrahigh-vacuum chemical-vapor deposition by Bernard S. Meyerson and his co-workers at IBM's Yorktown Heights research facility. They took the ultrahigh vacuum (UHV) of molecular beam epitaxy tools and a conventional chemical-vapor deposition (CVD) process and combined them in a technique that exploits the unique role of hydrogen in regulating the chemistry at the silicon and SiGe growth interface. Thin strained layers of the alloy are deposited on silicon wafers by a UHV/CVD batch tool with the doping and thickness control needed for manufacturing. (The wafers are 200 mm in diameter and have previously been patterned with implants and isolation.) As the tool can process multiple wafers simultaneously, throughput is high and cost is low.

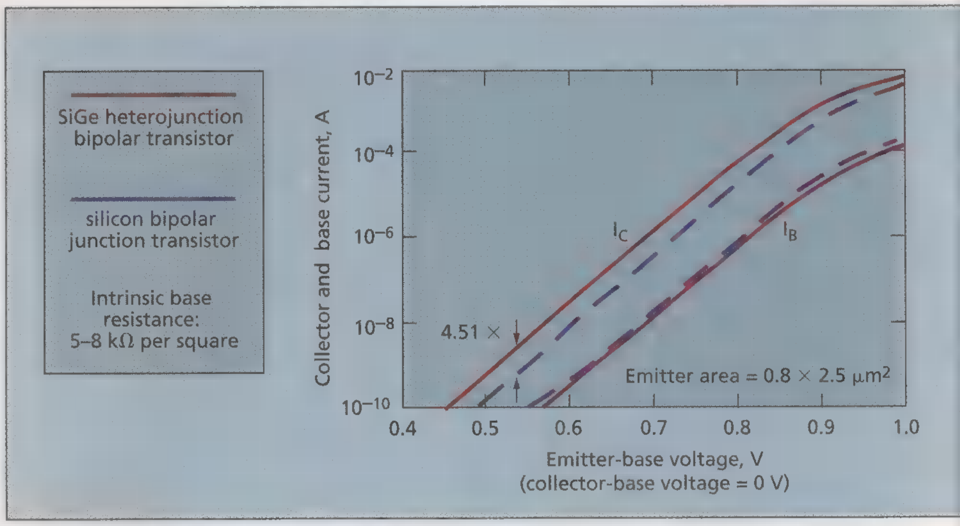
What SiGe buys you

From a device designer's viewpoint, it is distinctly beneficial that the energy bandgap of SiGe alloys is smaller than it is for silicon, lying as it does between silicon's 1.12 eV and germanium's 0.66 eV. The bandgap is further diminished by the compressive strain in the alloy layer (the bandgap shrinks faster with increasing germanium content than might otherwise be expected).

In strained SiGe grown on a silicon substrate, most of the bandgap reduction is due to a valence band offset (about 75 meV for each 10 percent of germanium). The conduction and valence band edges of the strained layers of SiGe lie within the band edges of the underlying silicon, a circumstance that favors the use of bandgap engineering to build fast transistors.

By III-V semiconductor standards, the band offsets in SiGe are not large. Even so,

▶ **Measurements of identically fabricated SiGe HBTs and silicon junction transistors allow unambiguous comparisons. In the first set of curves, the smaller base bandgap of the SiGe HBT enhances the collector current for a given bias, yielding a larger current gain. The drift field induced by the germanium grading reduces the base transit time and so improves frequency response [next set of curves]. A substantial increase in peak cutoff frequency from 30 GHz to [illegible] GHz is observed with the graded SiGe base. The last set of curves compares the unloaded gate delays of a SiGe HBT ECL ring oscillator with those of an oscillator made with silicon junction transistors. The improved frequency response of the SiGe HBT translates into improved large-signal switching performance.**



a big advantage can be gained by the controlled grading of germanium with growth techniques such as UHV/CVD. In practical SiGe devices, grading from 0 to 15 percent germanium may occur over distances as short as 50–60 nm, yielding induced electric fields of 15–20 kV/cm. Such very large fields soon accelerate charge carriers to saturation velocity, about 1 x 10^7 cm/s, promising very fast devices.

One final benefit of employing SiGe strained layers is that the carrier mobility is enhanced by the presence of strain in the alloy. This good fortune translates directly into lower-resistance layers for majority carriers and reduced transit times for minority carriers—both beneficial for realizing fast transistors.

From materials to devices

The base region of a bipolar transistor is critical to device speed, since this parameter is fundamentally limited by the time the carriers take to cross the base (base transit time). In effect, the base must be designed to be as thin as possible. Moreover, the useful collector current of a transistor is determined by the bandgap and doping profile of the base region (p-type for an n-p-n device). Since the dc and ac properties of the bipolar transistor can be strongly influenced by manipulating the base, the region is an obvious candidate for bandgap engineering using strained layers of SiGe. It is, in fact, a new and powerful lever for the silicon device designer to use in device optimization for specific applications.

To yield a superior transistor, the base region must be thin to remain stable, must have a smaller bandgap than silicon, and must be capable of forming p-type SiGe (p-SiGe). The last of these requirements entails controllable doping with boron at high dynamic range.

This, then, is the basic idea behind the SiGe heterojunction bipolar transistor (HBT). Using an epitaxial growth technique such as UHV/CVD, germanium is selectively introduced into the base region of a conventional silicon bipolar junction transistor. The p-SiGe base thus creates an emitter-base heterojunction (n^+-Si/p-SiGe) as well as a base-collector heterojunction (p-SiGe/n-Si).

Advanced self-aligned SiGe HBTs are built at IBM's advanced microelectronics production facility in East Fishkill, N.Y. Films of the alloy are deposited by means of UHV/CVD on a 200-mm wafer [see cross section, p. 50]. Apart from this step, the device is essentially identical to a conventional silicon bipolar junction transistor and is built with processing equipment common to any advanced silicon fabrication facility.

The physics of the novel HBT is largely determined by the specifics of the doping profile. When secondary ion mass spectroscopy is used to measure dopant concentrations in one of the transistors, the device is shown to have a peak germanium content of only about 7.5 percent, be only 70 nm wide, and as a consequence be unconditionally stable as grown [see profile, at top of p. 51].

How it all works

THE SMALLER BASE BANDGAP of the SiGe HBT is exploited in three ways, which can best be understood by considering an energy band diagram of the transistor [see lower diagram, p. 51]. First, note the reduction in base bandgap at the emitter-base junction. This base bandgap reduction exponentially increases the collector current for a given bias voltage, so that there is a large increase in current gain compared with a silicon bipolar transistor. What has happened is that germanium (with its smaller bandgap) has been added to the emitter-base junction to lower the potential barrier at the junction. In effect, for a given bias, more electrons are injected from emitter to base, where they contribute to the collector current.

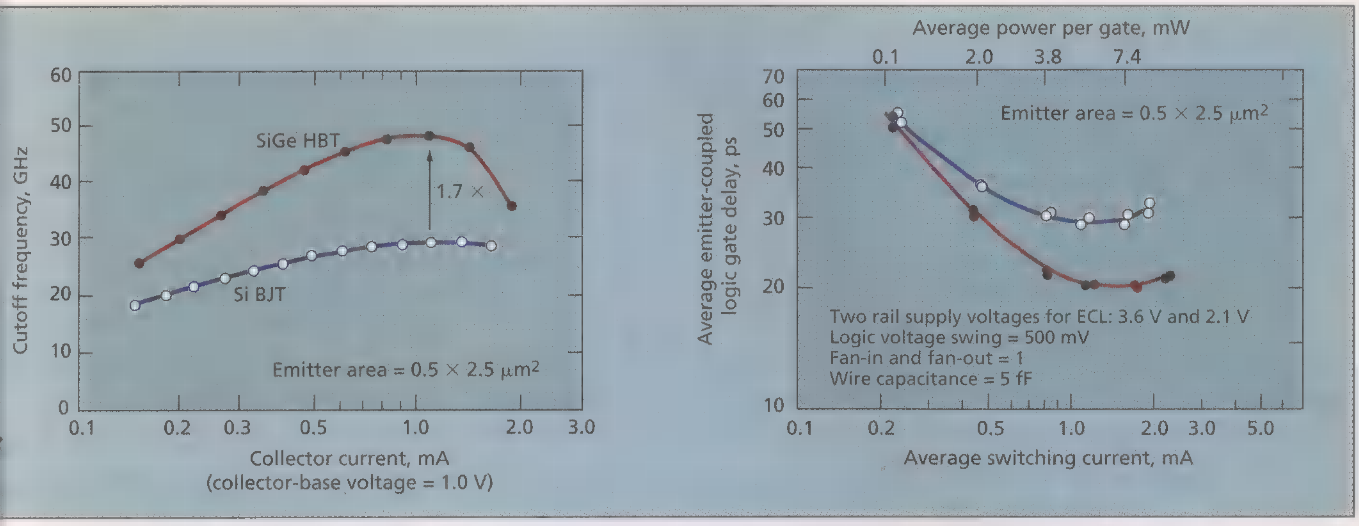
Secondly, if the germanium content is graded across the base region of the transistor, as is easy to do with the UHV/CVD technique, the conduction band edge becomes dependent on position, inducing an electric field in the device. This field accelerates injected minority electrons as they traverse the base. The base transit time of the SiGe transistor is thereby shortened, and its frequency response much improved [center set of curves, above].

Recent studies at the Daimler-Benz Research Laboratories as well as at IBM's Yorktown Heights facility demonstrate that, as noted earlier, the upper bound on cutoff frequency in aggressively designed SiGe HBTs is well above 100 GHz, more than a factor of two higher than the best achieved in silicon, and comparable to many GaAs-based technologies. Of note, too, is the fact that the IBM group achieved a peak cutoff frequency of 113 GHz in a device that has an intrinsic base sheet resistance of only 7 kΩ per square .

Finally, SiGe improves the output resistance of the transistor, a crucial feature in analog design. Of help in this context is the Early voltage, a measure of the ease with which the majority carrier profile in the base is depleted by an applied base-collector bias. For a SiGe HBT with a germanium grading from emitter to collector, the Early voltage increases exponentially with the amount of bandgap grading across the base.

In effect, the position dependence of the bandgap of the graded-base SiGe profile weights the base profile toward the collector region. The base region therefore becomes harder to deplete than for the comparably doped silicon transistor and yields a larger Early voltage.

Now, a transistor with a large Early voltage has a very flat common-emitter output characteristic and hence high output resistance. For the devices depicted in



the curves above, the Early voltage of the SiGe transistor is 53 V, nearly three times the 18 V for the silicon device.

Moreover, cooling enhances all the afore-mentioned attributes of the SiGe HBT. In striking contrast to the silicon junction device, the current gain, cutoff frequency (f_T), and maximum oscillation frequency (f_{max}) all rise significantly as the temperature drops. This means that the alloy transistor is well suited to operation in a cryogenic environment (say, at the temperature of liquid nitrogen, 77 K), historically the exclusive domain of silicon CMOS and III-V compound semiconductor technologies.

Cryogenic electronics is in growing use for both military and commercial applications such as space-based satellites, high-sensitivity instrumentation, high–transition-temperature superconductors, and future cryogenic computers. The SiGe technology quite naturally and for the first time extends the capability of silicon-based bipolar technology to include this challenging environment.

The games people play

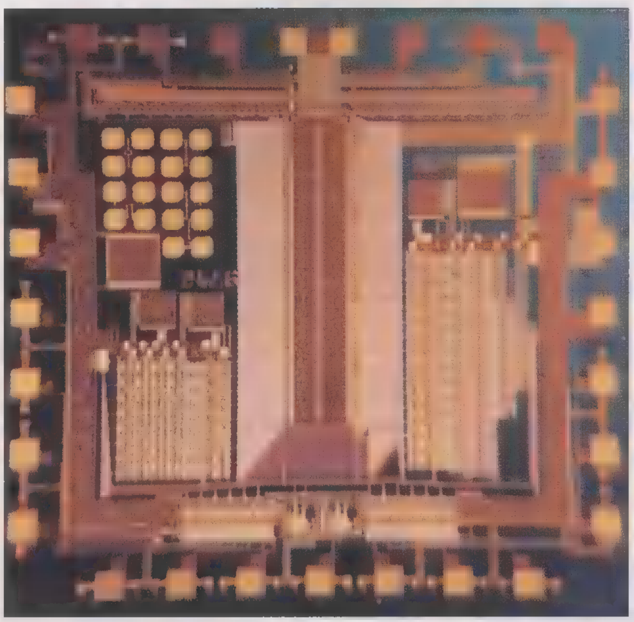
Going beyond its superiority to its silicon counterpart in current gain, cutoff frequency, and Early voltage, the newcomer's biggest asset is perhaps its potential for bandgap engineering. In effect, the device designer is enabled to selectively tune each parameter to a required specification. The only constraint for a practical SiGe transistor design is that the integrated germanium content be low enough to guarantee film stability.

In the silicon junction transistor, the collector current is determined solely by the shape of the base doping profile. But in the SiGe HBT, the collector current, and hence current gain, is effectively decoupled from the base doping profile design. In fact, the current gain of the SiGe HBT can be made large or small, depending on the shape of the germanium profile.

In analog designs, for instance, which frequently require large current gain, more germanium can be placed at the emitter-base junction. Here the optimum germanium profile might be a box rather than a triangle [see diagram, p. 51]. Conversely, current gain in digital designs, which typically do not require it to be high, can be traded for higher base doping and hence lower base resistance. That is, instead of using the germanium to increase the current gain from (say) 100 to 300, the decision might be to triple the base doping. The resulting transistor would still have a current gain of 100, but only one-third the base resistance (current gain is inversely proportional to base doping level).

Because the base transit time limits the frequency response of a bipolar transistor, a high-performance design must have a narrow base. In conventional silicon junction transistors, the region is formed by implanting boron. With low-energy ion implantation, though, the width of the base can be shrunk only by lowering the boron dose (atoms per square centimeter) and therefore the doping level. At the same time, the resistance of the base depends reciprocally on its doping level, so lowering the doping raises the resistance. In practice, the narrowest base width achievable with ion implantation is about 100 nm for a tolerable base resistance.

For the conventional silicon junction transistor, then, there exists an inevitable design tradeoff between good frequency response and low base resistance. With SiGe, bandgap engineering can be used to relax this tradeoff. The ideal, of course, would be high cutoff frequency and low base resistance (high f_{max}), since the latter is a better indicator of large-signal circuit speed than is the cutoff frequency. Therefore the semiconductor alloy is deposited in very thin, yet heavily doped layers,



STEVE BEST, AUBURN UNIVERSITY

This 1-gigasample-per-second, 1-W, 12-bit digital-to-analog converter makes use of 2854 SiGe HBTs and 1465 polysilicon resistors and is wired with three levels of metallization. It is the first commercially available SiGe integrated circuit.

with a graded germanium profile that boosts frequency response. The simultaneous achievement of high cutoff frequency and low base resistance is a key difference between the SiGe HBT and the silicon junction transistor.

An important figure of merit for the performance of high-speed analog applications is the product of a transistor's current gain and Early voltage (βV_A). The analog designer desires the largest possible value of this product, yet in the case of a silicon bipolar transistor, designing for high current gain is diametrically opposed to designing for large Early voltage. To be specific, reducing the base doping level yields a large current gain but makes it easier to deplete the base under base-collector bias (low Early voltage). At the same time, raising the base doping raises the Early voltage, but at the cost of current gain. The challenge, then, of achieving high βV_A in a transistor that still has good frequency response is a formidable one.

The situation is very different with the SiGe HBT. There, the βV_A product depends exponentially on the germanium content at the base-collector junction. A triangular germanium profile, for instance, yields high βV_A and high cutoff frequency.

Some applications

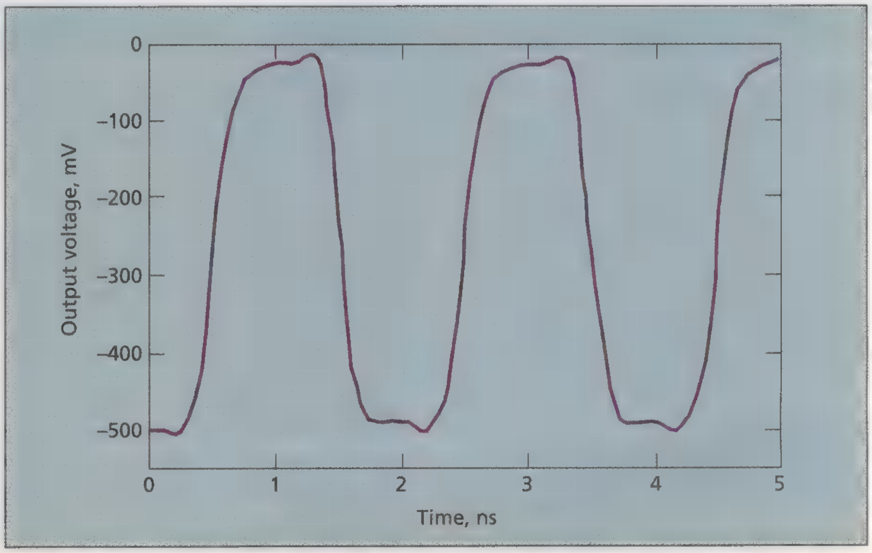
Initially, SiGe HBT technology was investigated with a view to high-speed digital logic applications. Emitter-coupled logic (ECL) circuits, as the *de facto* standard for fast bipolar logic, were fabricated in SiGe and tested to quantify their advantages over comparably designed silicon circuits. One measurement compared unloaded state-of-the-art SiGe ECL circuits with their silicon counterparts. The newcomers were found to switch every 20 picoseconds at 1.2 mA of collector current—a speed advantage of nearly 9 ps [see curves, p. 53 at right].

From the standpoint of a key consideration, power dissipation, this improvement translates into a halving of the power consumed by a switching event, given a constant speed of about one per 30 ps. Larger gains in performance are expected for optimized circuits, whose total base resistance would be reduced by leveraging the higher current gain of the SiGe HBT. In addition, for circuit configurations whose speed is more strongly coupled to frequency response than it is in ECL (examples are nonthreshold logic circuits or active pull-down circuits), SiGe HBTs may well show an even greater advantage.

All the same, the SiGe HBT is perhaps best suited for high-speed analog applications, which can truly use fast transistors with low base resistance, low noise, excellent high frequency response, and large βV_A product. To prove the point, a 12-bit, current-output, digital-to-analog converter with an ECL interface has been designed, built, and tested [see photo, p. 53]. It is the first commercially available SiGe IC.

Fabrication employed the UHV/CVD technique in IBM Corp.'s advanced semiconductor production facility in East Fishkill, N.Y., in alliance with Analog Devices Inc., Wilmington, Mass. The converter contains 2854 SiGe HBTs, 1465 polysilicon resistors, a patterned p^+ ground plane to speed signal settling, and three levels of metal for interconnections. It is the highest level of integration attained to date by SiGe HBT technology.

It bears repeating that the digital-to-analog converter achieves an update rate of 1.0 gigasample per second at less than 1.0 W [see waveform above], a record performance for silicon technology, and comparable to the best GaAs converters.



The measured output of the digital-to-analog converter of the prior figure makes full-scale transitions from all 0s to all 1s in 1 ns—performance comparable to the best GaAs versions.

Preliminary studies indicate that SiGe HBT technology is ideally suited to other historically demanding analog functions. These include low-noise, high-bandwidth amplifiers, mixers, and voltage-controlled oscillators, all key functions for radio-frequency and low-end microwave communication systems.

To date, power-added efficiency, a key figure of merit for high-bandwidth amplifier design, has been measured to be as high as 70 percent in SiGe HBTs, nearly double that of silicon junction transistors and comparable to the figure of merit for GaAs MESFETs. Transistor noise often constrains the design of communication systems. Early measurements of SiGe HBTs indicate that for low-frequency (less than 10 kHz) and high-frequency (2–10 GHz) noise, they are comparable to the best available GaAs devices. Recent reports aver that SiGe technology permits corner frequencies as low as 300–400 Hz and noise figures of 0.5 dB at 2.0 GHz and 0.9 dB at 10 GHz.

With the growing concern for power management in VLSI systems and portability for wireless communications, SiGe HBT technology has another compelling advantage: the fact that it can be integrated with conventional CMOS silicon circuits to form a biCMOS technology in which the bipolar transistors are SiGe HBTs. Here, the SiGe HBTs can be exploited for critical high-speed analog or digital functions and the silicon CMOS can serve for very high-density memory or compact on-chip signal-processing functions. The ability to integrate SiGe HBT with CMOS processes sets the new technology apart from the III-V technologies, which cannot supply the high-quality native oxide essential to implementations in CMOS.

As early as 1992, a fully integrated SiGe biCMOS technology was demonstrated at IBM's Thomas J. Watson Research Center. UHV/CVD served for alloy growth and conventional optical lithography for pattern definition. The result included SiGe HBTs with 0.5-µm geometry, CMOS FETs with 0.25-µm geometry, decoupling capacitors, and polysilicon and ion-implanted resistors. In this biCMOS process, the SiGe devices attained a cutoff frequency of 50 GHz, a record maximum oscillation frequency of 60 GHz, and unloaded ECL gate delays as short as 19 ps. The CMOS devices yielded state-of-the-art extrinsic transconductances of 240 mS/mm and 140 mS/mm for the n- and p-type transistors, respectively.

The numerous coming wireless applications could benefit from the economical integration of complex radio circuitry. For

instance, a mixed-signal SiGe BiCMOS technology could be used to build a radio on a chip that would operate at 2.0 GHz and above. Because a silicon substrate (unlike a GaAs one) is inherently conductive, the high-Q capacitors and inductors required are harder to make. Even so, precision monolithic silicon inductors with Q exceeding 10 have of late been demonstrated, and the prospects for improvement look bright as knowledge of silicon micromachining techniques grows.

Intriguing possibilities

While the HBT is the most mature device yet built with SiGe technology, a number of other potentially useful devices have been shown to work. Films of the alloy have been used to fabricate a variety of SiGe-channel MOSFETs, modulation-doped n- and p-channel high-electron-mobility transistors (HEMTs), pnp HBTs, and resonant tunneling diodes. All promise to far outperform their silicon counterparts. For instance, in p-channel MOS transistors, it has been shown that a channel that is 20 percent germanium improves the low-field hole mobility of a SiGe version by 50 percent over an all-silicon device (both transistors having 0.25-μm features).

Then, too, the ability to fabricate both p-channel and n-channel HEMTs on the the same silicon wafer raises the interesting possibility of a complementary SiGe HEMT technology. A configuration of that kind would be tough to realize with III-V semiconductors.

In the realm of photonics, an assortment of SiGe photodetectors has already been made and operated, including p-i-n, avalanche, and superlattice-based photodiodes. The smaller bandgap of germanium compared to silicon enables these diodes to absorb longer wavelengths, in the range of 1.3 μm. But III-V compound semiconductors, with their direct bandgap and hence excellent light-handling capability, still enjoy a decided advantage over SiGe, which remains an indirect bandgap material like silicon.

All the same, device designers have long dreamed of silicon-based optoelectronics, which would combine electronics and photonics on the same silicon chip. As envisioned by R. Soref of Rome Laboratories at Hanscom Air Force Base in Massachusetts, such a silicon superchip might have SiGe HBTs, complementary SiGe HEMTs, and conventional CMOS for high-speed analog functions, signal processing, memory, and computation, together with photodiodes for light detection, and silicon-based lasers for light emission.

Because silicon's poor light emission is the biggest obstacle to realizing an optoelectronic superchip of this kind, several research groups are exploring more complicated silicon-based alloys such as silicon-germanium-carbon and silicon-germanium-tin. They hope to discover one that emits light yet stays compatible with conventional silicon fabrication.

As was the case with SiGe HBT technology, SiGe photonic devices cannot hope to compete head-to-head with the GaAs or InP technologies in sheer performance. Rather, they should deliver a better combination of cost and performance. Whatever may be the eventual commercial impact of these more exotic SiGe devices, the alloy suggests many interesting possibilities for the future, a healthy sign in any new technology.

The road ahead

The bottom line is economics. To succeed commercially, SiGe technology has to outperform silicon technology and undersell the III-V technologies. To this end, SiGe ICs must look, taste, feel, and smell like silicon ICs, yet compete in speed with their GaAs cousins.

Offhand, the performance constraint seems manageable, while the eventual cost of SiGe technology will rest on its compatibility with conventional silicon fabrication. It should be noted, however, that state-of-the-art silicon technology (be it CMOS or bipolar) derives a large fraction of its cost from the multilevel metallization and packaging. Thus, no dramatic impact on cost is expected when epitaxially grown SiGe films replace conventional ion implantation for the formation of the transistor base region.

Of course, as new transistor technologies go, SiGe is still an infant. Nevertheless, the signs are encouraging, especially for SiGe grown with UHV/CVD, which has a proven capability on 200-mm wafers in an advanced silicon production environment. The future is bright as the age of silicon-based bandgap-engineered technologies rapidly approaches. Watch out, GaAs, silicon is on the march again! ◆

To probe further

The electrical and mechanical properties of the SiGe strained-layer epitaxy are described in "Physics and Applications of Ge_xSi_{1-x}/Si Strained Layer Heterostructures," by R. People in the *IEEE Journal of Quantum Electronics*, Vol. 22, 1986, p. 1696.

A review of the UHV/CVD growth technique and its application to a variety of semiconductor devices can be found in "UHV/CVD growth of Si and SiGe alloys: chemistry, physics and device applications," by B.S. Meyerson, in the 1992 *Proceedings of the IEEE*, Vol. 80, p. 1592.

The basic idea of the heterojunction bipolar transistor can be traced to H. Kroemer's pioneering 1957 paper, "Theory of wide-gap emitter for transistors," *Proceedings of the IRE*, Vol. 45, p. 273. The first SiGe HBT was reported in "Silicon-germanium base heterojunction bipolar transistors by molecular beam epitaxy," by S. S. Iyer and co-workers (*Technical Digest of the International Electron Device Meeting*, 1987, p. 874). In 1990, the performance potential of SiGe HBT technology was clearly demonstrated for the first time in "75 GHz-f_T SiGe base heterojunction bipolar transistors," by G.L. Patton and others (*IEEE Electron Device Letters*, Vol. 11, p. 171). Later that year, the first fully integrated SiGe HBT circuit technology was reported in "Profile leverage in a self-aligned epitaxial Si or SiGe base bipolar technology," by J.H. Comfort and his colleagues (*Technical Digest of the 1990 International Electron Device Meeting*, p. 21).

Recent demonstrations of some very aggressive SiGe HBT technologies with cutoff frequencies exceeding 100 GHz can be found in "High-speed SiGe-HBT with very low base sheet resistivity," by E. Kasper and company, in the 1992 *Technical Digest of the International Electron Device Meeting*, p. 79, as well as in "Vertical profile optimization of very high frequency epitaxial Si- and SiGe-base bipolar transistors," by E.F Crabbé and colleagues, in the 1993 IEDM *Technical Digest*, p. 83.

In the same IEDM volume, on p. 784, D.L. Harame and others outline the circuit technology used to realize the 1.0-gigasample-per-second 12-bit SiGe digital-to-analog converter in "Optimization of SiGe HBT technology for high-speed analog and mixed-signal applications." Chip architecture and design details of the 12-bit SiGe DAC can be found in "Combining silicon and germanium yields 1-GHz, 12-bit DAC," in the Feb. 7, 1994, issue of *Electronic Design*.

The longer-term prospect for SiGe and other silicon-based bandgap-engineered materials for future photonic applications is reviewed in "Silicon-based optoelectronics," by R. A. Soref, in the *Proceedings of the IEEE*, Vol. 81, 1993, p. 1687.

About the author

John D. Cressler is assistant director of the Alabama Microelectronics Science and Technology Center as well as associate professor of electrical engineering at Auburn University in Alabama. His research interests include silicon-germanium device physics and technology, cryogenic electronics, device simulation, and circuit modeling. Prior to joining Auburn University in 1992, he spent over eight years with IBM Corp.'s Thomas J. Watson Research Center, Yorktown Heights, N.Y., where he was a member of the team that developed IBM's SiGe heterostructure bipolar transistor technology. He is a Senior Member of the IEEE, and in 1994 was awarded the Office of Naval Research Young Investigator Award for his SiGe research program.

WILSON GREATBATCH

Wilson Greatbatch orders a dessert of chocolate cake. When the waitress serves him, he quips: "I wish you'd flipped it over. Then I'd have negative calories!"

The waitress smiles, politely. Engineering is seldom far from Greatbatch's mind. He's a prodigious inventor and tinkerer. Among his projects are a solar-powered canoe, cloned African violets, engines that run on alcohol, and nuclear-powered batteries. In all he has over 140 U.S. and foreign patents, including the one for the implantable pacemaker.

In 1983, the National Society of Professional Engineers chose the pacemaker as one of the 10 greatest engineering contributions to society during the past 50 years. In 1988, Greatbatch was inducted into the National Inventors' Hall of Fame, in Akron, Ohio, for patent No. 3 057 356. He follows in the famous footsteps of Thomas Alva Edison, Alexander Graham Bell, and William George Armstrong.

Yet he is the consummate family man, too, with five children and six grandchildren after over 50 years of marriage. He lives not far from where he was born, in Buffalo, N.Y., and is active in his community. Every fall during the apple-picking season, he hosts a cider-making party. He once owned several Caterpillar bulldozers and occasionally did some earth-moving services for the townspeople. (The town returned the favor a few times by helping him with town zoning on some of his large-scale projects, such as building of factories or digging a 3-hectare lake.)

But first and foremost, Greatbatch is an old-style independent inventor. He has never accepted a government research grant. And whenever a company he helps to create becomes too big, he leaves to pursue his own ideas elsewhere.

Wayward beginning

Intangible things—like music, religion, and radio waves—have fascinated him since his childhood.

An only child of parents who were "relatively poor," he evinced an interest in electricity and electronics early on. "I think it was the mystery of it," he said. "Something was happening that you couldn't see, or feel, or hear. You needed a meter or oscilloscope or at least a neon bulb to detect it and you had to interpret what the reading meant."

In his early teens he built a two-tube short-

JOHN A. ADAM
Senior Associate Editor

The inventor of the implantable cardiac pacemaker—and holder of 140 other patents—lives modestly in upstate New York while he pursues AIDS research

wave receiver and listened to London on a coil he had wound himself. Around 16, he passed the test for an amateur radio license (W8QBD). An active Boy Scout, he joined the Sea Scout Radio Division, which had a station (W8QBU) near the New York State Naval Militia in Buffalo. The station received a Red Cross citation for staying on the air 26 hours straight during the 1938 New England hurricane, to relay messages to other ham stations in Ontario and Ohio.

The station generated social get-togethers, too. A group of girls who called themselves MAD (Men Are Dogs) hung around the Sea Scouts' radio shack and, to the boys' dismay, made curtains for it. "Most of the guys finally married most of the girls, as did I, eventually," Greatbatch said.

In 1939, Greatbatch and many of the other Sea Scouts joined the Naval Reserve unit nearby, all qualifying for a noncommissioned officer's grade because of their radio licenses. They practiced their radio drills while sailing to New York City and Guantanamo, Cuba.

Over the course of World War II, the Sea Scouts trained more than 50 radio operators. Greatbatch served five years. Among his duties were repairing electronics on a destroyer, serving as radioman on convoys to Iceland, teaching radar in Texas, and finally flying in the Pacific as a rear gunner off the USS *Monterrey* aircraft carrier. In six months of combat, a third of the squadron crew was killed.

After the war, Greatbatch returned to Buffalo

Greatbatch designed pacemaker circuits on manila folders and attached components opposite the sketch. Nowadays he uses such "working pacemakers" for classroom demonstrations. He hooks up a battery at one end, while a transistor radio amplifies the circuit's life-giving rhythm for all to hear.

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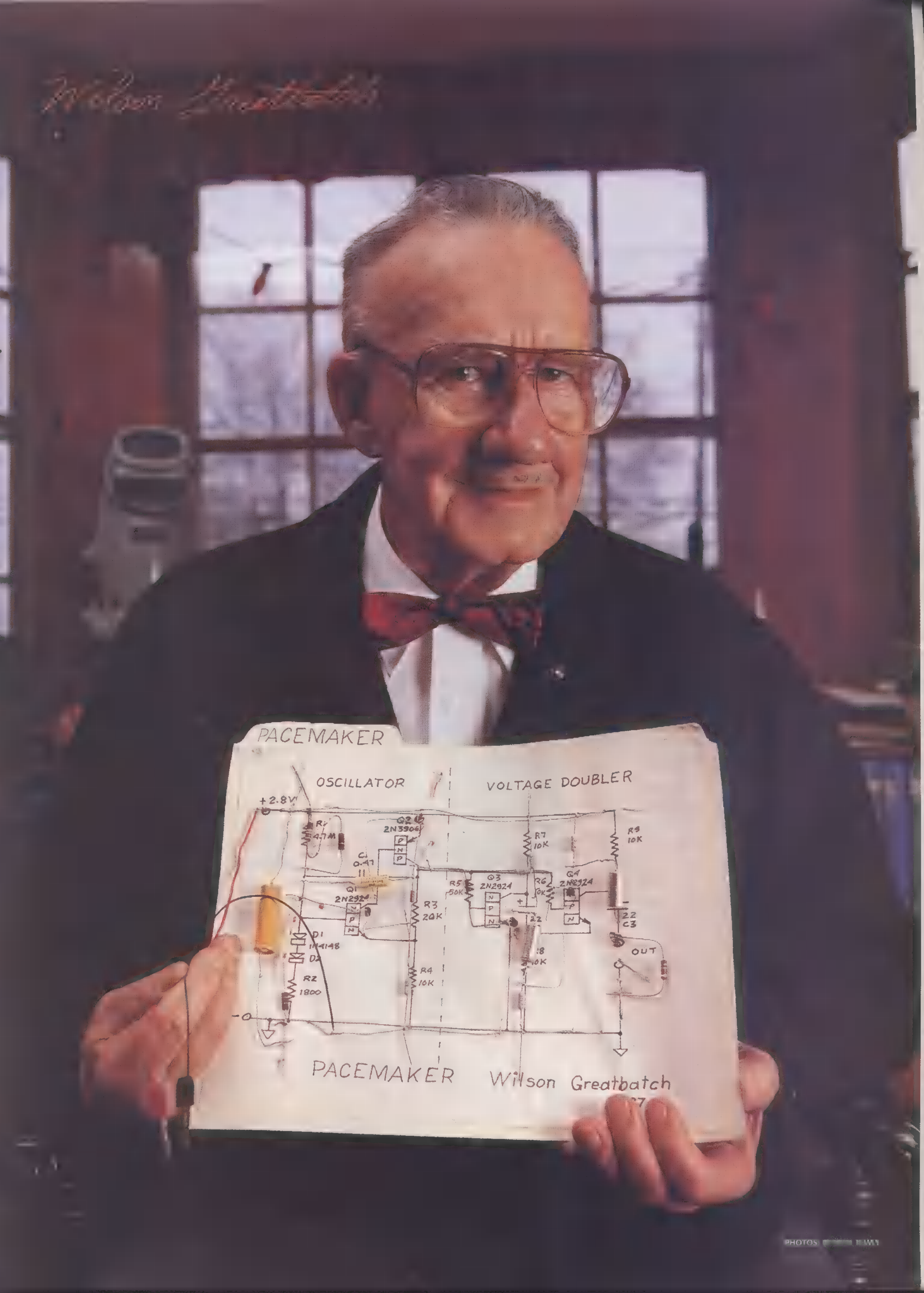
PACEMAKER
OSCILLATOR
VOLTAGE DOUBLER
PACEMAKER
Wilson Greatbatch

PHOTOS

Vital statistics

Name: Wilson Greatbatch
Born: Sept. 6, 1919, in Buffalo, N.Y.
Personal: married in 1945, five children, six grandchildren
Religion: Presbyterian Elder
Education: Cornell (BSEE, 1950) and Buffalo (MSEE, 1957) universities; also several honorary doctorates
First job: repairing radios in a Buffalo repair shop in 1938 for $12 a week
Interests: gardening, sailing
Languages: English, French, German, technical reading proficiency in Russian
Pet peeves: venture capitalists; the U.S. Food and Drug Administration (medical device–regulating agency)
Management credo: create a hands-on, personal relationship in the workplace, grow on profits, stay out of debt
Personal hero: Thomas Edison
Favorite authors: Herman Melville, James Michener
Favorite composers: Bach, Vivaldi, Copeland
Favorite award: National Inventor's Hall of Fame
Patents: over 140 internationally (including 41 U.S. patents, more than half in his name only)
Memberships: National Academy of Engineering, Fellow in the following: New York Academy of Sciences, American College of Cardiology, Royal Society of Health (UK), American Institute of Medical and Biological Engineers; American Society of Angiology; the IEEE, among others
Personal philosophy: "Don't fear failure, don't crave success. Just immerse yourself in the problem and work hard. The true reward is not in the results but in the doing."

with his bride, Eleanor, a home economics teacher, who would become his laboratory assistant and his maker of bow ties as well. He worked a year as a telephone repairman before enrolling at Cornell University in Ithaca, N.Y. "After all that time in the dive-bombers with the ack-ack [anti-aircraft fire] bursting all around, you appreciate the change," he told *IEEE Spectrum*. "I was so grateful. I have repeatedly and vainly tried to imbue my children with the kind of appreciation that I had, just for the opportunity to sit, and hear, and learn. I don't think I ever got this across to them."

He gives Cornell credit for its emphasis on a broad engineering education steeped in mathematics, physics, and chemistry. The breadth of his studies enabled him later to branch out into nuclear physics, electrochemical polarization of physiological electrodes, battery chemistry, the physics of welding, and more.

Soon, with several children to support, Greatbatch as a student needed to double his GI Bill income from the Federal government. He started as an electronics technician building receivers for what became the Cornell radio telescope at Arecibo, P.R. Eventually he inherited a job at the Psychology Department's animal behavior farm: doing instrumentation on around 100 sheep and goats (for blood pressure, heart rate, brain waves, and other measurements).

During 1951, Greatbatch used to share brown bag lunches on the farm with two New England surgeons, who were there on summer sabbatical. They described an ailment called heart block, which occurs when natural electrical impulses from the heart's upper chambers (atria) fail to reach the ventricles in adequate quantity. The result is irregular heartbeats that can cause shortness of breath and, in extreme cases, loss of consciousness and even death.

"When they described it, I knew I could fix it," Greatbatch recalled, "but not with the vacuum tubes and storage batteries we had then."

He did not know it at the time, but Paul Zoll in Boston made the first practical external pacemaker in 1952. About the size of a table radio, it could be plugged into household current. Though treatment was painful and damaged the skin, the device could save lives. Several years later, Earl Bakken, the founder of Medtronic Inc., developed a hand-held external pacemaker that was powered by batteries.

In the meantime, Greatbatch had returned to Buffalo to teach at the university as an assistant professor of electrical engineering. (Teaching was his original career goal.) He also did some work at the nearby Chronic Disease Research Institute. By then, around 1956, commercial silicon transistors had become available for US $90 each, and Greatbatch, qworking for a doctor, was making a 1-kHz marker oscillator with one transistor to aid in the recording of fast heart sounds.

The oscillator required a 10-kΩ resistor at the transistor's base. "I reached into my resistor box for one but misread the colors and got a brown-black-green [of 1 MΩ] instead of a brown-black-orange," he said. When he plugged in the resistor, the circuit started to "squeg" with a 1.8-millisecond pulse, followed by a 1-second interval, during which the transistor was cut off and drew practically no current. "I stared at the thing in disbelief," he said.

This, he at once realized, was exactly what was needed to drive a human heart. The circuit was self-starting and its output would remain constant despite drops in battery voltage. For the next five years, most pacemakers were to use a blocking oscillator with a United Transformer Co.'s DOT-1 transformer—all because he had grabbed the wrong resistor.

Barn exile

Buffalo was the site of the world's first local chapter of the Institute of Radio Engineers' Professional Group in Medical Electronics, which is now the IEEE Engineering in Medicine and Biology Society (EMBS). Greatbatch was a founding member. The group strove to attract equal numbers of doctors and engineers, and had a standing offer to send an engineering team to assist doctors on any instrumentation problem.

Greatbatch was on one team that had been summoned by William C. Chardack, chief of surgery at Buffalo's Veteran's Administration Hospital, to deal with a blood oximeter. The engineers could not help with that problem, but the meeting for the inventor was momentous: finally, after many previous attempts, he had met a surgeon who was enthusiastic about prospects for an implantable pacemaker. The surgeon estimated such a device might save 10 000 lives a year.

Three weeks later, on May 7, 1958, the engineer brought what would become the world's first implantable cardiac pacemaker to the animal lab at Chardack's hospital. There Chardack and another surgeon, Andrew Gage, exposed the heart of a dog, to which Greatbatch touched the two pacemaker wires. The heart proceeded to beat in synchrony with the device, made with two Texas Instruments 910 transistors. Chardack looked at the oscilloscope, looked back at the animal, and said, "Well, I'll be damned."

In a lab book entry in 1959, Greatbatch reflected on that moment: "I seriously doubt if anything I ever do will ever give me the elation I felt that day when my own two cubic inch piece of electronic design controlled a living heart."

The threesome (called the bow-tie team because none of them ever wore dangling ties, a convention Greatbatch upholds to this day) later put anesthetized dogs into complete heart block. As there was no heart-lung machine, the operating team had to work fast. The team closed off the large vessels, opened the heart, occluded the atrioventricular bundle with the tied suture, closed the heart, and reopened the artery—all within about 90 seconds.

"We were pretty naive about early pacemaker designs," their inventor observed. "We thought that wrapping the module in electric tape would seal it." The team soon found that the slightest void in the wrapping would fill with fluid and

short out the circuit. That first implant lasted 4 hours. Switching tactics, they began to cast the unit in a solid block of epoxy. Within a year, survival time rose to four months. It was time now, they felt, to look for a suitable human patient.

Greatbatch's then employer, Taber Instrument Corp., was loth to risk a million-dollar company on a perilous item like the pacemaker, so Greatbatch left. (But he did continue to work as an instrumentation consultant to the company, which was involved in some space shots of monkeys for the astronaut program.)

As with so many other inventions, an implantable pacemaker was the goal of several groups during the late '50s—from General Electric Co. to Swedish researchers. In Sweden, Ake Senning had attempted the first human implant late in 1958. The unit failed after 3 hours. A second unit worked for eight days before failing, and the patient had to wait for three years before receiving a satisfactory unit.

Perhaps Greatbatch owed his success to his demanding deadline. He had saved enough to feed his wife and three young children plus enough ($2000) to devote himself full-time to his task for just two years.

"I put it to the Lord in prayer and felt led to quit all my jobs," he said. He retreated to his workshop, a barn heated by a wood-burning stove. There he made some basic discoveries. One was that uninsulated wires bond better with epoxy. He would glue components together, hand-solder the circuit, and fit it into a pack of batteries. This packet was then encased in a block of epoxy and cured overnight at a 37 °C. Several silicone coatings were applied and the unit was then trimmed with a scalpel. Serial numbers were imprinted on the uncured silicone.

In two years, on his $2000 savings, he made 50 pacemakers by hand. Not all had the same design, and the number of batteries used ranged from three to 10. Forty of his units would go into animals as improvements were made. At the same time, he was developing reliability procedures.

▲ **Cutaway of an early 1960s' pacemaker "explanted" from a patient shows the problematic zinc-mercury batteries and epoxy-encased circuitry. Improvements, many led by Greatbatch, have enabled today's pacemakers to frequently outlive millions of patients.**

During 1960, starting on April 15, Chardack and his associates implanted pacemakers in 10 patients, most over 60 years of age. Two were children. All had complete heart blocks, so that without pacemakers they had perhaps a 50-percent chance of living more than a year.

The first patient lived 18 months. Another of the initial group was a young man who had collapsed on his job at a local rubber factory. After receiving a pacemaker, he retrained as a hairdresser and has only recently died, after being paced for 30 years, much of this time with a plutonium-powered pacemaker.

Greatbatch's first pacemakers to be successfully implanted in human patients consisted of pulse-generating circuitry linking two transistors, four to 10 zinc-mercury batteries of 1.35 V, and leads attaching the unit to the ventricle. Its lifetime rhythm was a 2-millisecond pulse of 5–8 V into the heart every second.

This device stood in for failed natural pacing and allowed a normal rate of invigorating fresh blood to circulate to all parts of the body. One of the inventor's "most gratifying realizations of what a pacemaker could do" came from watching grandparents interact with grandchildren. "With the pacemaker," he said, "grandpa could be in the mainstream again."

Medtronic man

In early 1961, at the Airways Hotel at the Buffalo Airport, Greatbatch signed a license for the implantable pacemaker with Medtronic Inc. Like Greatbatch, Medtronic's president Bakken was an EE who taught Sunday school. The struggling company operated out of a garage in Minneapolis and repaired TV sets when work was slow. As remuneration for his design, Greatbatch agreed to receive stock shares.

It was the beginning of Medtronic's Chardack-Greatbatch Pacemaker, which would dominate the field for the next decade, in spite of the innovations of many competitors. Greatbatch made monthly trips from Buffalo to attend meetings, sign off on drawings, and monitor production quality. He learned that a fingerprint on a transistor anode lead, for instance, would leave enough salt to corrode it.

Chardack "sold" the Medtronic device to the medical profession through his papers, case reports, and personal recommendations. Greatbatch credits him with much of the company's early success, but others credit Greatbatch, too. Said a competitor of the Buffalo engineer: "All salesman hustle their product, but he did his in an honest fashion."

Medtronic is still the world's top producer of theurapeutic implantable devices, with sales of $1.4 billion in 1994. Pacemakers accounted for 67 percent of that revenue.

But Chardack's job was no easy sell. At that time, it was anathema to most surgeons to leave anything in the body after surgery. But it turned out that the pacemaker was the ideal catalyst for the development of internal biomedical devices.

First of all, the heart had a high profile with the general public. Also, the pacemaker was relatively low risk. If the device failed, the patient did not necessarily die. (For the vast majority of patients, the pacemaker was to be a life enhancer rather than a life saver. For the critical patients of the early days, almost

anything was better than nothing.)

Circumstances were favorable biologically, too. Cardiac muscle is much easier to stimulate than, say, the smooth muscle of the bladder. Cardiac fibers are self-excitatory and interconnected in a latticework so that an impulse applied locally to an atrium or ventricle will spread over the whole heart spontaneously, causing the organ to contract. In contrast, an impulse on the corner of ■ bladder will contract only that corner. (Only recently have clinical tests of systems for electrical stimulation of bladder control begun.)

But, even with these advantages, the pioneers of implants had ■ tough time. The body itself—warm, wet, and saline—is not hospitable to electronics. Greatbatch calls it more demanding than the deep ocean or space environment. Implanted devices must be rugged enough to defend themselves against onslaught from the body, yet at the same time be neutral enough not to counterattack and harm the inhospitable host.

"Many judgments had to be made by the seat-of-our-pants because there just wasn't much data around on the long-term behavior of materials in the body," the veteran inventor said.

Pacing on demand

Fixed-rate pacing was fine for the critical patient. But most people required only stimulation on demand, initiating a heartbeat only when it was needed. Such a sensing capability would prolong battery life and had been described in the literature.

Greatbatch's lab notebook states that his first successful breadboard of the implantable inhibited-demand pacemaker was completed in January 1965, resulting in Medtronic Model 5841, the first on the market (although Cordis Corp., Miami Lakes, Fla., had put out another type of demand pacemaker earlier).

Parts that did make it into a Medtronic unit were rigorously tested. Early transistors—fromTexas Instruments, General Electric, and Transitron—had no consistent reliability. Greatbatch segregated them into beta (current gain) classes and put them through five cycles, from dry ice to heat soaking at 125 °C, for 500 hours.

In a shock test, any transistor that developed leakage or drifted more than one beta class was discarded. About 30 percent of the transistors were winnowed out, but none of the survivers was ever lost in ■ pacemaker.

In the early days, to bake transistors, Greatpatch set up two ovens in his bedroom. His wife, Eleanor, administered the shock test. "Many mornings," he said, "I would awake to the cadence of Eleanor 'tap, tap, tapping' the transistors" with a pencil. For some months, every transistor used in Medtronic pacemakers was tapped in the Greatbatch bedroom in Clarence, N.Y.

Despite the pains taken to ensure reliability of componentry, many patients during the early years of artificial pacemaking died. Others were inconvenienced by unanticipated reactions or by the repeated surgery needed to change pacing units.

Aside from initial corrosion problems with electrodes, all the early pacemakers required difficult surgery. The chest had to be opened and electrodes sewn directly onto the surface or the middle layer of the heart. Ten percent of these poor-risk patients died from the surgery alone.

Later Chardack refined an existing technique in which a lead with a spring coil was inserted through a vein into the interior of the heart. This procedure permitted pacemakers to be implanted under local anesthesia without opening the patient's chest.

GREATBATCH GEN-AID, LTD.

▲ The first implantable pacemaker in 1958, used on ■ dog, was wrapped in tape in hopes of protecting it against body fluid. Epoxy encasement ■■■ soon found to work much better.

Once the pacemakers were implanted, the body encased them in a collagenous sheath so tightly that when the units were taken out for new models or batteries, the Chardack-Greatbatch imprint and serial number were seen, backwards, on the collagenous growth. Said Greatbatch of the internal tattoo, "We felt this was really leaving our mark."

Heartbeat power

The great inventor admits that if he had not come up with the implantable pacemaker, someone else would have. "Most new developments are like that—not somebody getting ■ Eureka flash," he observed. What distinguishes him perhaps is his dedication to improving his invention.

This took several forms. One was giving advice freely. Recalled Walter Keller, who designed pacemakers in the 1960s for top rival Cordis Corp.: "We shared ideas. Since Bill was ahead of me, I got plenty of help from him."

Another was going outside his original training to develop better batteries. In ■ 1959 paper, Greatbatch had predicted a five-year average life for a pacemaker. In 1970, however, pacemakers were lasting an average of only two years. The problem was the power supply. Around 80 percent of those removed (called explants) were traced to a failed zinc-mercury battery, which used technology developed during World War II, modified in 1958 for the electronic wristwatch market.

Besides a relatively short shelf life, mercury batteries produced gas and therefore could not be hermetically sealed. Encasement in semipermeable epoxy was required. This did the critical job of keeping corrosive salt ions from the body out, but the electronics essentially operated immersed in distilled water. "Circuits in pacing drew so little current that the slightest problem could cause shunting," Keller recollected. And any contamination on the wiring would cause corrosion.

In 1968, Greatbatch had set out on two paths for power sources: one used halide cathodes with lithium as an anode, and the other used nuclear batteries based on plutonium 238.

Collaborating with Hittman Corp. of Columbia, Md., Greatbatch and a Hittman team designed a clinically successful plutonium battery that would have lasted the lifetime of even the youngest patients. But problems due to factors such as radioactivity and toxicity made them undesirable. Even a microgram ingested can be fatal.

In the early '70s, after numerous experiments with a variety of lithium batteries, Greatbatch and his colleagues adapted a lithium iodine power source to the high-reliability demands of pacemakers. It had been recently invented by James Moser and Allan Schneider. Batteries are complex systems to design well. In fact, a bad battery design ultimately caused Cordis Corp. to abandon pacemaking. Keller called Greatbatch's adaptation superb. "That guy, he's not only good, he's lucky!"

Greatbatch's confidence in this lithium battery was so great that he created a company to manufacture them. Today, the $30 million company, which is run by his oldest son, Warren, still sells or licenses over 90 percent of the world's pacemaker batteries.

The lithium battery's advent has been called the most significant improvement for the pacemaker since its invention. Not only does the battery boast greater reliability and a higher power density than others, but it does not produce gas. Lithium batteries enabled pacemakers to be laser-welded in metal cannisters for a hermetic seal. At last circuitry and batteries could operate in a dry, moisture-free environment.

The battery innovation helped another top biomedical company. When Manny Villafana, a friend of Greatbatch's from Medtronic, was setting up Cardiac Pace-

makers Inc. (CPI) in Minneapolis, Greatbatch advised him that lithium batteries were too new and too risky for a company just starting out. But Villafana said he needed "something completely new" to establish the company.

For over a year, Greatbatch's firm sold him the lithium batteries without billing CPI. It also supported CPI in selling the device and in straightening out some technical issues. The alliance proved mutually successful. Lithium batteries are still the main power source in pacemakers, extending their average life beyond 10 years.

Tempting questions

During his career, Greatbatch's curiosity has lured him into many projects that failed. That category included his work on bone growth stimulation, closed-loop control of drug delivery, electronic control of infection, and creating orange trees impervious to frost damage. But his need to search for answers has also led him to tackle such problems as energy supply and, most recently, AIDS.

It was the energy crisis of the early '70s that induced him to clone plants and trees as a biomass source of fuel. He figured that 50 000 people using two fields of 61 km^2 could become independent of other forms of energy. He cloned a hybrid poplar tree in the sterile laboratory environment that could produce up to seven tons of dry wood per acre per year and would regenerate after being cut to stump level.

Greatbatch planted 40 000 of the trees, successfully composted two years of sewage sludge from a nearby town, and even modified his 1967 Dodge truck to run on wood alcohol. The goal was complete energy independence, but the end of the oil crisis and state environmental rulings put a damper on his efforts. He did, however, give cloned flowers to friends, including a miniature rose under 7 mm in diameter that was cultivated in a test tube; he named it "Rosemary Cloney."

Self-sufficiency and "the idea of getting something for nothing" were the reasons behind Greatbatch's building of a 380-W solar-powered canoe, in which he cruised around the Finger Lakes on his 72nd birthday. He submitted results of his 230-km voyage to the *Guinness Book of World Records*, hoping that someday its editors would establish such a category for the book.

"I'm sure my record will be quickly surpassed, but that doesn't matter," he said. "The joy of accomplishment is not in the results, but in the doing. It was great fun. Now maybe I can grow old gracefully."

Greatbatch (not himself the user of a pacemaker) is certainly not taking it easy. For the last decade he has investigated the human immunodeficiency virus. With John Sanford of Cornell Universitiy, he was able

'He's just a learner. If something is new, it doesn't bother him a bit. Whenever he does anything, it's a total immersion.'

—Eleanor Greatbatch, Wilson's wife of 50 years

to inhibit a similar viral replication in cats. The two were recently awarded U.S. Patent No. 5 324 643 for this work. To help his studies, he has bought a computer and modem to access the Internet from his home.

In praise of principles

Greatbatch likes to point out that "profession" has religious origins, deriving from monasteries, which were considered the repository of knowledge and where one "professed" his faith. Ethics and values are central. Money is not.

It is interesting to note that during the first 16 years of pacemaker manufacturing, no Federal regulation covered the monitoring of safe practices and trials. Practitioners—like Greatbatch—tackled the job scrupulously and did well.

Strengthening the engineering profession has been one of the inventor's ongoing commitments. Early in his career, in the nascent field of biomedical engineering, he insisted that engineers receive top billing in their professional journals while doctors would receive the marquis spot in medical journals.

He believes that engineers should participate in projects at both local and national levels. Last summer, he lobbied on Capitol Hill for rules affecting international patents. At the state level, he feels biomedical engineers should be registered as professional engineers because they carry a social responsibility in helping to treat patients.

Always a booster of education, Greatbatch, friends note, has donated millions to schools, creating an engineering wing at local Houghton college, for example. Moreover, he has seen to it that his employees and their children seeking a university education have had their tuition and books paid for.

In spite of such great accomplishments, Greatbatch has no big ego. His children have a fancier life-style than he does. In person, he speaks softly, simply, and straightforwardly (like Gary Cooper, in a way). His wife Eleanor said, "He's just a learner. If something is new, it doesn't bother him a bit. Whenever he does anything it's a total immersion."

He learns mainly by talking to people, reading, and experimenting. Yet most of the time, she said, he works unhurriedly. Herb Mennen, an engineer and partner of Greatbatch's for more than 20 years, said, "He works a normal day. But geniuses do things differently."

To make an impact in engineering requires "complete immersion, a long time, maximal professionalism, and a subordination of those false values that the rest of the world deems so important," Greatbatch wrote in 1983. Citing the New Testament (First Corinthians 10:24), he said the other person's welfare should be more important than your own. "This is a shocking statement. American business doesn't run that way. But when a customer finds out you really mean it, most won't buy anywhere else."

Those themes are prominent in Greatbatch's favorite speech, which lasts about 2 minutes. He first delivered it in 1987 at a Clarkson University commencement in Potsdam, N.Y. Now he recites it by heart. Realizing that parts are preachy and that references to the Lord may fall upon unwilling ears, he nonetheless plans to continue giving the speech his way, he told *Spectrum* last November.

And so in fact he does that night at the IEEE/EMBS awards dinner, where both he and Bakken of Medtronic are being honored. Many in the audience, like the handful of students sitting at this writer's table, are not even sure who the elderly gentleman in the blazer and bow tie is.

But by the middle of the speech, no one is looking at the tines of the dessert forks. The speaker's sincerity has drawn everyone in. He urges the listeners, "Don't fear failure. Don't crave success," and reminds them that "the reward is not in the results, but rather in the doing." At least for a few minutes, an audience is spellbound. ◆

THE IN-HOUSE SPRINGBOARD TO SUCCESS

Your company's help-wanted ads can lead to a better job right under your nose

JOHN A. HOSCHETTE
Loral Infrared and Imaging Systems

THE BEST STARTING POINT FOR CAREER development is your own company's system for filling job openings from within. In fact, if you are not aware of the system and how to benefit from it, you could already be missing out on a good opportunity for advancement.

Typically, the personnel department will post the job openings periodically. Companies realize that most frequently the best candidate for a newly available position is someone already on their payroll. Drawing on the pool of existing employees means less time and effort spent on training than if someone is hired from outside. So you as an employee may well have an edge over an outsider.

Job openings may be listed in the company newspaper, or posted on bulletin boards, or accessible through the company computer network. Do you read these listings? It amazes me how many people will read the daily newspaper's sports, financial, or arts sections, or the comics, but hardly ever scan the company's list of job openings. To get ahead, you should be reading these lists continually, as you can never tell when a better opportunity will present itself.

Actually, you ought to be in a constant job-search mode, both inside and outside your company. You should be constantly reviewing the job listings of trade journals and newspapers. You may even want to contact one or more professional search firms to do some searching for you.

What the job ads teach

Job ads will provide you with a wealth of knowledge about the job market and your chances for advancement at any given time. By studying your company's notices, you can quickly tell which divisions are hot and hiring—and which may be having difficulty because they have no openings.

How is your division doing? If it is hiring, chances for promotion in your present department are good.

Study the listings further. Do they identify the job level, type of engineer required, and pay level? Consider the experience and background being sought. The kind of training most of the job ads are seeking will indicate the background you may need to rise in the ranks. If all the openings are for chemical engineers and you are a software engineer, you may find it hard to get ahead.

Compare your pay with the salaries on offer. If you are being underpaid, it's time to move on. If the level is comparable, you can be satisfied, at least for the time being.

Also review the salaries for jobs one level above yours. Would you like a raise and a promotion? Well, how will you find out whether you qualify unless you go for an interview? Remember, your supervisor may be restricted in the salary increase he or she can offer you, but a different supervisor might be more at liberty to give you a raise because in that other department you would be a new hire.

As you study the ads, determine which of the divisions have openings and what you would be working on if you joined them. What products are under rapid development? Which divisions and products are stagnating? Is there any chance of transferring to a new division or product line and picking up a promotion on the way over?

A word of caution about your own company's job openings: the typical organization has an internal policy regarding promotions. Of course, it wants to put the most suitable person into a position, not just whomever the supervisor wants. So the latter will frequently be required to advertise that the position is open and to interview all likely candidates.

What this often means is that an opening will be posted even if the boss already has someone in mind for the job. Some research is therefore of the essence even before you respond to a job listing at your company. Try to find out if someone is already in line for the vacancy. And when you

Adapted from Chapter 5 of *Career Advancement and Survival for Engineers* by John A. Hoschette (with permission, John Wiley & Sons Inc. [800-225-5945], 1994, 200 pp., $39.95 cloth, $15.95 paper). For earlier adaptations from this book, see *IEEE Spectrum*, November 1994, pp. 96–99; December 1994, pp. 42–44; and February 1995, pp. 56–58.

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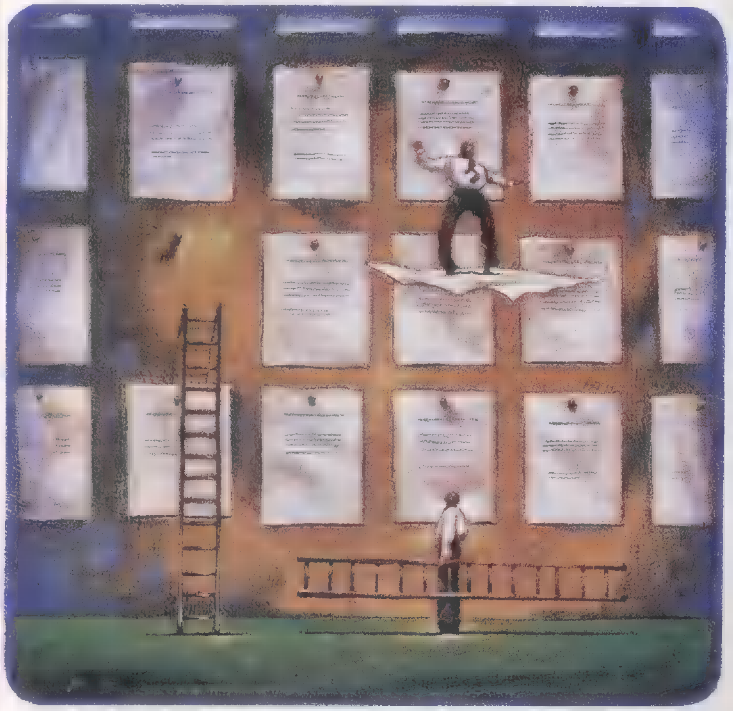
are finally interviewing, ask the supervisor the obvious question: "Is anyone interviewing who is presently in your group?" If the answer is yes, that person is more than likely the best candidate and it is ■ "done deal," as they say.

Besides studying your own firm's job listings, you should constantly be checking the job ads of your company's competitors in the trade journals and newspapers. Are they hiring? What type of people are they looking for? What are they willing to pay employees with a similar background to yours? Which are your competitors' growing and expanding divisions and product lines? Are they looking for your level of background and experience or for some other type? All these questions can be answered through studying the job listings. And all this information is important for your career development.

The next question to arise is, "What do I do if I find something?" The answer is straightforward.



PAUL ANDERSON

Go and check it out. You should check at least once ■ year for other job opportunities through some type of job interview.

There are three reasons why this matters. First, it will keep your interviewing skills sharp and your résumé updated. Second, it may bring you a better opportunity for promotion. Third, you may find out that your job is not so bad after all. In any case, you benefit from the experience and lose nothing—well, it should be nothing.

Many people react to the reasons for pursuing career advancement enumerated earlier with, "That's great, but if my supervisor finds out, I'll lose my job." If this is really the case, I strongly recommend you make a change immediately. You do not want to be working for that type of person.

If your supervisor does find out that you are exploring new opportunities, there are several things that you can say that should do more good than harm to your career. First, you can say that you are happy where you are and have no desire to leave, but you heard of this opportunity and thought you would just check it out. After all, it seems a wonderful opportunity, and no one aspiring to rise professionally would fail to look into it.

Alternatively, you might shower your supervisor with compliments. For example, you can point to the great job she or he did developing you. You might argue that the chief reason you feel you stand ■ chance for ■ better opportunity is the excellent training you've received.

Still another approach, if you are unhappy with your present position and rate of growth, is to be frank and open. Tell your supervisor that you see little opportunity where you are and you feel that you must explore the options.

Candor is likely to elicit one of two reactions, both helpful. You might be told that there really is little hope for you in this group and you should probably look elsewhere. This is valuable information about how your supervisor perceives you and what your real chances for advancement are. It confirms your decision to search for other work.

The other reaction is an expression of concern and ■ declaration of how much you are wanted and how valuable you are. You have now opened the door to further discussions about your possible advancement. Seize the chance to outline your career objectives, and with any luck, the two of you will work out ■ plan to get you what you want.

In other words, use the opportunity to start planning your next promotion together. If the rapport between the two of you is good, you might point out that it's easier for your boss to give you the promotion than to spend time on training ■ new person.

Whatever you are told, keep on tracking down job opportunities. If one arises within your company, be sure you inform your supervisor before you talk to the person doing the hiring. It is professional courtesy, and besides, it will only end up hurting you if someone else leaks the news.

Of course, discretion is always the better part of valor. Job shopping should be a very low-profile activity. If you are too visible and start interviewing in too many places, your ambition can backfire. Your supervisor will quickly find out what you are doing and want to know why. Do not volunteer any information unless you are asked directly. And don't discuss your plans with co-workers—they could go running to the boss the minute you leave their office.

When you go for the interview, you had better

have good answers to some tough questions. The first is usually: "Does your present supervisor know you are interviewing?" An excellent answer is that your supervisor does know and does not want to stand in the way if this is really a good career move.

A second and equally difficult question is: "Why do you want to leave?" One response is to say that you are looking for a better opportunity and that you thought this might be one. Whatever else you do, do not speak negatively about your present position. Act as if anything you say about your supervisor or group will immediately be spread all over the company.

Remember that soon after you leave the interview, the first thing the hiring supervisor will do is call your present boss. And how that person responds can make or break your chances.

If your present chief thinks highly of you, he may respond with, "He is a great employee and I don't want to lose him." Whereupon the hiring supervisor will probably want you all the more. But a response such as, "He is a marginal performer and I'd like to get rid of him," could end everything immediately.

The important point here is that if you don't know how your supervisor will react, you are taking a big risk. You should know what that reaction will be before you spend time interviewing. Keeping on good terms with your boss during this whole process is essential.

But being on poor terms with the person over you need not mean the end of a job switch within the company. The effect of a poor relationship could be good or bad—I have witnessed both dénouements.

On occasion supervisors want to get rid of someone. Rather than fire whoever it is, they find the person new opportunities and may even pass along great performance recommendations.

At other times a supervisor seizes the opportunity to get even and on purpose underrates the employee's performance and spoils any chance at advancement. If your relations with your supervisor are poor, you might want to ask outright how he or she would react before you go through all the effort to switch jobs within the company. Watch the reaction. If it is a "get even" response, you will have to deal with it. You cannot ignore it.

Bidding up the job offer

After you get a job offer, your work is still not done, regardless of whether the offer comes from inside or outside your present company. In either case, the ideal is to get your present supervisor to make a counteroffer in the hopes of keeping you.

You should tell your boss what's up. Explain why the offer appeals to you and why you intend to leave if no counteroffer is made. The intent here is to try to extract an even better deal from your present supervisor. (If you would prefer not to leave at all, you must definitely give your boss a chance to match the offer.)

Ask your supervisor to come up with at least as good an offer. It is surprising how fast some can move and how much they can counteroffer when afraid of losing a key performer. Sometimes another offer helps build a case for promoting you. If someone else thinks you promotable, why shouldn't your present supervisor think so, too? It may be all that is needed to push some supervisors to action. It hurts their ego to know that someone else in the company is trying to steal their people.

If you get your supervisor to counter the offer, your battle is still not over. Take that offer and see if the new supervisor can do better. Your goal is to get both supervisors to offer absolutely the most they can. You repeat this process until neither of them can offer any more. At this point you win.

Some engineers feel this is unethical or not normal. To this I say: look at other professions, sports in particular. Athletes even go as far as hiring agents to negotiate job opportunities for them. Actors, actresses, lawyers, and nearly every other professional person do the same thing. Knowing how to negotiate is essential for career advancement.

Comparing the prospects

WHEN THE BEST AND FINAL offers are in, you need to consider career aspects other than status and salary. It's the best of all possible worlds if you change jobs for a promotion and stay within the company. You keep your seniority and your vacation and retirement benefits. Studies show that an engineer who stays with one company until retirement will in most cases leave in better shape than one who has changed jobs. This is so even if the person changing companies has had larger pay raises.

Remember, more than a simple pay raise is involved when you consider leaving a company. Leave and you lose vacation and retirement benefits. You may also incur extra expenses. For instance, you may have to drive farther to work or move out of state. In the latter case, there will be the costs of changing your car insurance, place of residence, driver's license, and real-estate fees, just to name a few. Is any of the raise left after you pay all the new expenses? How will your retirement benefits be affected? For example, a 3 percent raise inside the company may be equivalent to a 6 percent increase outside.

Another point to weigh is that at the new company you will be starting over. You cannot expect a large raise any time soon. It may take you over a year to reestablish your position and your performance. So, if you get a raise when leaving, make sure it's large enough. It may be a long time before you get another.

When your move is blocked

If your present supervisor tries to block your move, you have several options. First, suggest a convenient transfer date some time in the future and try to get your supervisor to agree to it. Let it be known that you are not going to leave the company high and dry. You should be able to work out some gradual transfer plan.

If your supervisor continues to fight you, you will have to play hardball. You point out what your reaction will probably be over time. At first, you will go on working hard, but after a while you will probably lose interest. It's hard for you to give it all you've got when you gave up a promotion and raise simply because your supervisor didn't think you should get it.

Explain that holding you back is not good for either of you or the company in the long run. Nobody wins in this type of situation. Or you might try volunteering your help in finding and training your replacement. This eases the transition.

If you win your supervisor round and do accept a raise and promotion elsewhere in the company, there is still a protocol to follow. Above all, thank your present boss for all past help. Point out all the good things your new supervisor liked in you, and indicate that you qualified for the new position in part because your old supervisor did so much for your development.

Never leave on bad terms. The ill will could come back to haunt you.

Homework

- Find out how your company's system of posting job openings works.
- Study the help-wanted notices. Do you know all the codes? What do the ads tell you? Which divisions are hot, which are not?
- Study the job ads in trade journals. What are they looking for and how much are they willing to pay?
- Pick a job opening at your company and go on an interview. ◆

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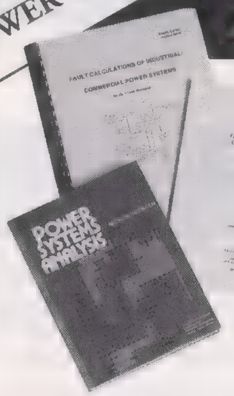

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The School of Engineering commenced operation in January 1992 with the formation of a Joint Faculty of Engineering between Flinders University and the University of South Australia, and the appointment of its Foundation Professor of Engineering. The School offers undergraduate and postgraduate degree programmes in Biomedical Engineering, Electrical and Electronic Engineering, and Information Technology and Telecommunications.

Modern, well equipped teaching and research facilities are being progressively established and the School is set to grow rapidly over the next 3 years. The University is seeking high calibre academic staff, with a demonstrated commitment to teaching and research, who will assist in shaping this future.

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Strong academic qualifications, preferably at PhD level, or equivalent industrial or research experience, and excellent written and oral English communication skills required for all positions. The senior appointees will have a substantial record of achievement, and be expected to assume a leadership role in Biomedical Engineering or other key areas including Communications Engineering, Digital Systems and Micro-computers, Signal Processing, and Electrical Machines and Drives.

Selection criteria and further information regarding opportunities and duties associated with these positions may be obtained from Professor Andrew Downing, Head, School of Engineering, phone (618) 201 3603, fax (618) 201 3618 or email egard@cc.flinders.edu.au. Applicants must indicate at which level they are seeking appointment, which at Lecturer level, is not normally made above A$46 946pa.

Applications, addressing the selection criteria, quoting the reference number, and giving full details of qualifications and experience together with the names, addresses and facsimile numbers of three referees of whom confidential enquiries may be made, should be lodged, in duplicate, with the Manager, Human Resources, Flinders University, GPO Box 2100, Adelaide SA 5001, Australia or fax (618) 201 3131 by 31 March 1995.

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Continued from p. 18T6

Walter H., AIP Press, New York, 1995, 623 pp., $45.

Coherent Optical Communications Systems. *Betti, Silvello, et al.*, John Wiley & Sons, New York, 1995, 539 pp., $69.95.

In Marconi's Footsteps - Early Radio. *Jensen, Peter R.*, Kangaroo Press/Seven Hills Book Distributors, Cincinnati, Ohio, 1994, 176 pp., $39.95.

Structured C for Engineering and Technology, 2nd edition. *Adamson, Tom, et al.*, Prentice Hall, Englewood Cliffs, N.J., 1995, 713 pp., $47.

Interactive SQL on the AS/400. *Hovell, John F.*, Prentice Hall, Englewood Cliff, N.J., 1995, 160 pp., $35.

Integrated Circuit Quality and Reliability, 2nd edition. *Hnatek, Eugene R.*, Marcel Dekker, New York, 1995, 808 pp., $195.

Efficient C Programming: A Practical Approach. *Weiss, Mark Allen*, Prentice Hall, Englewood Cliffs, N.J., 1995, 529 pp., $36.

Passive Optical Components for Optical Fiber Transmission. *Kashima, Norio*, Artech House, Norwood, Mass., 1995, 342 pp., $85.

The Third Culture: Beyond the Scientific Revolution. *Brockman, John*, Prentice Hall, Englewood Cliffs, N.J., 1995, 432 pp., $25.

Parallel Computing: Principles and Practice. *Fountain, T. J.*, Cambridge University Press, New York, 1994, 346 pp., $39.95.

Detection of Light: From the Ultraviolet to the Submillimeter. *Rieke, G.H.*, Cambridge University Press, New York, 1994, 344 pp., $59.95.

Industrial Ecology. *Graedel, T.E.*, and *Allenby, B.R.*, Prentice Hall, New York, Englewood Cliffs, N.J., 1995, 412 pp., $37.

Rdb: A Comprehensive Guide, 2nd edition. *Hobbs, Lilian*, and *England, Ken*, Digital Press, Newton, Mass., 1995, 463 pp., $39.95.

Network and Internetwork Security: Principles and Practice. *Stallings, William*, IEEE Press/Prentice Hall, Englewood Cliffs, N.J., 1995, 462 pp., $55.

Implementing Concurrent Project Management. *Turtle, Quentin C.*, Prentice Hall, Englewood Cliffs, N.J., 1994, 222 pp., $45.

Strategic Alliances: An Entrepreneurial Approach to Globalization. *Yoshino, Michael Y.*, and *Rangan, U. Srinivasa*, Harvard Business School Press, Boston, 1995, 272 pp., $29.95.

Power Programming with Gupta SQLWindows. *Lalwani, Rajesh*, Prentice Hall, Englewood Cliffs, N.J., 1995, 328 pp., $29.95.

Comprehensive Project Management: Integrating Optimization Models, Management Principles, and Computers. *Badiru, Adedeji B.*, and *Pulat, P. Simin*, Prentice Hall, Englewood Cliffs, N.J., 1995, 548 pp., $60.

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Rdb: A Comprehensive Guide, 2nd edition. *Hobbs, Lilian*, and *England, Ken*, Digital Press, Newton, Mass., 1995, 463 pp., $39.95.

Network and Internetwork Security: Principles and Practice. *Stallings, William*, IEEE Press/Prentice Hall, Englewood Cliffs, N.J., 1995, 462 pp., $55.

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Power Programming with Gupta SQLWindows. *Lalwani, Rajesh*, Prentice Hall, Englewood Cliffs, N.J., 1995, 328 pp., $29.95.

Comprehensive Project Management: Integrating Optimization Models, Management Principles, and Computers. *Badiru, Adedeji B.*, and *Pulat, P. Simin*, Prentice Hall, Englewood Cliffs, N.J., 1995, 548 pp., $60.

calendar

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Custom Integrated Circuits Conference—CICC '95 (ED, SSC); May 1–4; Westin Hotel, Santa Clara, Calif.; Melissa Widerkehr, Widerkehr and Associates, Suite 610, 1545 18th St., N.W., Washington, DC 20036; 202-986-2166; fax, 202-986-1139.

Fourth International Symposium on Integrated Network Management—Isinm '95 (COM); May 1–5; Red Lion Hotel, Santa Barbara, Calif.; M. Olson, Isinm '95, Box 22605, Santa Barbara, CA 93101; 805-569-1222; fax, -2227; e-mail, isinm@ cs.ucsb.edu.

Particle Accelerator Conference (NPS); May 1–5; Hyatt Regency, Dallas; B. Montoya, Los Alamos National Lab, Box 1663, MS H850, Los Alamos, NM 87545; 505-667-5634; fax, -665-8604; e-mail, Beckym@ lanl.gov.

Annual Textile, Fiber and Film Industry Technical Conference (IA); May 2–4; Hyatt Regency, Charlotte, N.C.; Robert D. Henderson, RDH Consultants Inc., Box 7264, Charlotte, NC 28241; 704-588-6538.

Fifth Workshop on Hot Topics in Operating Systems (C); May 4–5; Rosario Resort, Orcas Island, Wash.; Michael Jones, Microsoft Corp., One Microsoft Way, Building 9S/1047, Redmond, WA 98052; 206-936-8846; fax, 206-936-7329; e-mail, mbj@ microsoft.com.

International Radar Conference (AES, NCAC); May 7–11; Radisson Mark Plaza Hotel, Alexandria, Va.; Tom Fagan, IEEE International Radar Conference, 1000 Wilson Blvd., 30th Floor, Arlington, VA 22209; 703-247-2988; fax, 703-276-9706.

Second International Test Synthesis Workshop (C); May 8–10; Red Lion Resort, Santa Barbara, Calif.; Ben Bennetts, Synopsys, 700 East Middlefield Rd., Mountain View, CA 94043; 415-694-4244; fax, 415-694-4128; e-mail, benb@synopsys.com.

Industrial and Commercial Power System Conference (IA); May 8–11; Menger Hotel, San Antonio, Texas; M. Osborn, 13622 Stoney Hill, San Antonio, TX 78231; 210-671-4095.

International Conference on Acoustics, Speech and Signal Processing (SP); May 8–12; Westin Hotel, Detroit; Al Hero, EECS Dept., 4229 Engineering 1, University of Michigan, Ann Arbor, MI 48109; 313-763-0564; fax, -1503; e-mail, hero@ dip.eecs. umigh.edu.

Intelligent Networks Workshop—IN '95 (COM); May 9–11; Ottawa Congress Center, Canada; Javan Erfanian, Stantor, Floor 6B, 33 City Center Dr., Mississauga, ON L5B 2N5, Canada; 905-615-6486; fax, 905-615-8421; e-mail, javan@comm.toronto.edu.

Power Industry Computer Applications Conference (PE); May 9–12; Salt Palace Convention Center, Salt Lake City, Utah; Robert Chisholm, PacifiCorp. Power Supply, 168 N. 1950 West, Salt Lake City, UT 84115; 801-220-2109; fax, 801-220-4895.

MANAGER POWER OPERATIONS

Martin Marietta Utility Services (MMUS), [redacted] subcontractor to the United States Enrichment Corporation (USEC), is seeking [redacted] highly motivated professional to join its Portsmouth, Ohio, Gaseous Diffusion Plant. This is one of two plants operated by MMUS which produces commercial grade enriched uranium for [redacted] in nuclear power plant reactors world wide. This position is responsible for providing strong leadership, planning and direction for the operation and maintenance of [redacted] high voltage transmission and distribution system in an industrial plant environment with a design capacity of 2260 MW's. Major responsibilities encompass providing executive, administrative, and technical direction to the Power Department to ensure a safe, efficient, reliable operation by maintaining the electrical system [redacted] the highest level of integrity with emphasis on safety, environmental, training, cost control, and quality assurance. This position is the principal contact with the power supplier and USEC on power contract [redacted] and other related technical matters involving the electrical power system. This position manages [redacted] activities of 65 to 70 employees (45 to 50 hourly) and [redacted] annual operating and power budget of $270 million dollars.

Requires as [redacted] minimum [redacted] B.S. degree in Electrical Engineering with [redacted] major in Power plus 10 years of experience in the operation and maintenance of [redacted] high voltage power transmission and distribution system with [redacted] least 5 years management experience of such [redacted] system. Must be knowledgeable of heavy industrial plant operations, processes and facilities and ANSI/IEEE/NEC/NESC/OSHA Codes and Standards for Electrical Safety. Requires effective communication, supervisory and management skills and ability to administer Company/Union contract. The applicant must physically be capable to oversee, monitor and perform field inspections on electrical equipment and jobs anywhere on plantsite. A Professional Engineering (PE) license is desired. Must be a U.S. citizen and be able to obtain [redacted] government security clearance.

Please send your confidential replies to:
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We offer [redacted] excellent compensation and benefits package in an exciting environment. For consideration, please send a resume to: **Staffing Department, Dept. LF/CCS, P.O. Box 12915, Shawnee Mission, KS 66272-2915.** We are proud to be [redacted] EEO/AA employer M/F/D/V. Also, we maintain [redacted] drug-free workplace and perform pre-employment substance abuse testing.

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A Special Opportunity Award [redacted] The Whitaker Foundation will allow the University of Tennessee, Memphis [UT Memphis] [redacted] the University of Memphis [U Memphis] individually to add faculty and [redacted] develop further their joint curriculum in BME. This collaboration draws upon substantial [redacted] in Memphis: [redacted] major universities, several teaching hospitals in [redacted] major medical center, including the nationally known St. Jude Children's Research Hospital, and three major implant manufacturers.

Both universities seek individuals with excellent capacity [redacted] teaching and research; candidates should present obvious potential to build a solid research program based on externally funded support. The positions described below are in tenure tracks and require an earned doctorate in engineering or [redacted] closely related field; post-doctoral experience [redacted] desirable. At each university, screening [redacted] applications will begin March 15, 1995 and [redacted] continue until each position [redacted] filled.

Faculty Position At U Memphis:

Candidates [redacted] the assistant or associate professor level are being sought who have [redacted] expertise in experimental [redacted] simulation [redacted] of electrocardiology. Applications from persons with unusually strong credentials in other electrically oriented aspects [redacted] BME [redacted] also encouraged. Applicants [redacted] send a Curriculum Vitae, [redacted] summary of their [redacted] plans, and names of three references to: Dr. Fritz Claydon, Chair of Search Committee, Department [redacted] Biomedical Engineering, The University of Memphis, Memphis, TN 38152, e-mail: fclaydon@admin1 .memphis.edu, phone: 901-678-2171

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Faculty Position At UT Memphis:

Candidates [redacted] the [redacted] professor level are being sought in two areas: (a) com-puter-oriented BME, particularly high performance distributed computing and clinical [redacted] support or (b) biomechan-ical engineering, especially physiological fluid flow, tissue engineering, and implant-able devices. Persons in other areas of BME who have particularly strong creden-tials [redacted] be considered. Applicants should send a Curriculum Vitae, a sum-mary of their research plans, [redacted] the names of three references to: Dr. E. Eckstein, [redacted] Com. Chair, BME, UT Memphis, [redacted] Madison Ave., Suite 801, Memphis, TN 38163, e-mail: [redacted] bme.utmem .edu, phone: 901-448-7099

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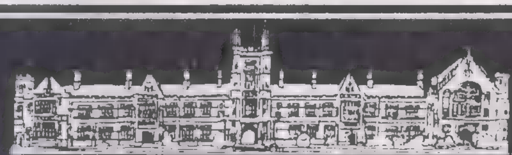

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Faculty of Engineering

LECTURER

Department of Electrical Engineering (Fixed Term or Tenurable)

Reference No: B01/03

The department is looking to expand its research and advanced teaching capability in the electrical Systems area. In line with a strategic plan which emphasises postgraduate studies an appointee with an understanding research career potential is sought. The position arises from the appointment to the Chair of Electrical Engineering of Professor David Hill. The existing staff in related areas have research interests in nonlinear and adaptive control, power systems, electrical vehicles, power electronic circuits, multidimensional systems, neural networks, artificial intelligence, communications systems, image processing, plasma engineering and optical fibre sensing. Generally, the department is vigorously developing its research work to the highest international standards. A special feature of this effect is the high level of interaction with industry, both local and international.

The appointee must have completed a PhD with a high level of research outcomes, have the capability to supervise research students and present advanced courses. Undergraduate teaching experience and experience of industrial applications are desirable. Preference will be given to applicants with analytical skills in the systems area, i.e. stability analysis, optimisation, synthesis, computational techniques and related subjects.

The position may be offered as a 5-year fixed term appointment or, for exceptional applicant, be offered as Tenurable appointment. Membership of a University approved superannuation scheme is a condition of employment for new appointees. For further information contact Professor David J. Hill on (61 2) 351 4647, fax: (61 2) 351 3847, email: davidh@ee.su.oz.au or the Head of Department, Professor Trevor Cole on (61 2) 351 2682, fax: (61 2) 351 3847, email: trevor@ee.su.oz.au.

Salary: Level B $A42,198 - $A50,111 p.a. **Closing:** 17 March 1995

Method of Application: Three copies of the application, quoting and Reference No, including curriculum vitae, list of publications and the names, addresses and fax numbers of at least three and not more than five referees to The Personnel Officer, (Group B), Link Building, (J13), The University of Sydney, NSW, Australia 2006.

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EEs' tools & toys

Exerciser plugs holes in PCI system development

Now that much of the computer industry has accepted the Peripheral Component Interconnect (PCI) bus, suppliers are under the gun to bring PCI-compatible products to market quickly. But sometimes schedules slip because developers must await delivery of certain application-specific chips or other hardware. The E2910A PCI Bus Exerciser from Hewlett-Packard Co. shortens the wait by simulating the bus traffic that the missing device ought to be there to generate.

▲ Comprising several plug-in cards [center], cabling, and an extensive array of Windows-based system software, the Hewlett-Packard E2910A PCI bus exerciser can deterministically simulate the bus traffic of a not-yet-available device, so that its absence need not hamper system development.

Nor is that all. The E2910A can also act as a bus controller, monitor, and recorder. It is, in sum, a general-purpose tool for developing PCI bus products.

Physically, the package consists of a suite of Windows-based system software, three cards, adapters, and assorted cabling. The test sequencer card plugs into a PC; the bus exerciser card plugs into the system under development by means of a choice of adapters; and an IEEE-488 card connects the PC with an HP 16500A/B logic analyzer. (Neither PC nor logic analyzer is supplied as part of the package.).

The test sequencer card, which runs at up to 33 MHz, controls the bus exerciser card. It allows the user to define complex sequences of transactions, with triggering or branching on system events detected by the logic analyzer or by the bus exerciser itself.

The bus exerciser generates user-defined transactions, whether acting as a master or a target. It includes a protocol monitor, which continually monitors 30 PCI protocol rules in real time. If it detects a violation, it generates a signal that may be used for triggering or branching. In addition, the bus exerciser also generates sideband signals synchronized to bus transactions.

The E2910A PCI bus exerciser sells for US $44 900. The required logic analyzer will add about $18 000 to that cost, and an appropriate 486- or Pentium-based PC may add a further $1500–$2000. *Contact: Hewlett-Packard Co., Direct Marketing Organization, Box 58059, MS51L-SJ, Santa Clara, CA 95051-8059; toll-free, 800-452-4844, ext. 8917;* or **circle 100.**

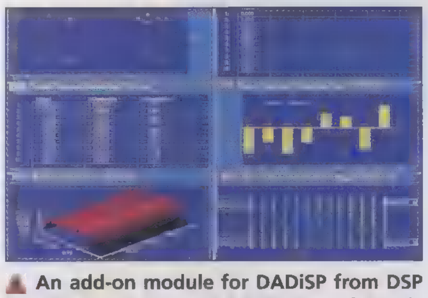
software

DADiSP now does neural nets

Of three new add-on modules for the popular DADiSP graphical scientific and engineering spreadsheet from DSP Development Corp., the most interesting enables users to build and run the back-propagation type of neural network. Called DADiSP/Neural Net, the add-on is a menu-driven module that could find wide application in such areas as speech and pattern recognition, image processing, and cluster analysis. The PC version of DADiSP/Neural Net is priced at $695 for PCs.

The other two modules do signal processing. The first, DADiSP/Filters 3.0, which offers finite- and infinite-impulse response (FIR and IIR) filtering functions, now includes Kaiser window filtering. The module allows both the time- and frequency-domain characteristics of a filter to be displayed and manipulated. The filter coefficients are displayed in a window of their own and saved in a system file for further use.

Over and above designing a host of common filters (such as Butterworth, Chebyshev, elliptical, Hilbert, and Remez), DADiSP/Filters 3.0 can calculate and plot the zeroes of an IIR or FIR filter; calculate the group delay of an IIR filter; and perform a variety of conversions from one filter type to another.



▲ An add-on module for DADiSP from DSP Development Corp., DADiSP/Neural Net is an algorithm for building and running back-propagation neural networks. As this screen shot illustrates, just about any aspect of the network's operation may be displayed and analyzed.

Finally, DADiSP/AdvDSP 1.0 performs a variety of advanced digital signal-processing functions—fast Fourier transforms (FFTs), power spectral density estimation, digital interpolation, and cepstrum analysis, to mention a few. It can execute over 20 high-level algorithms, such as chirp Z transforms, zoom FFTs, Yule-Walker linear prediction, and Burg method (maximum entropy) estimations.

DADiSP/Filters 3.0 and DADiSP/AdvDSP 1.0 are each priced at $495 for PCs and $995 for workstations. *Contact: DSP Development Corp., One Kendall Square, Cambridge, MA 02139; 617-577-1133; fax, 617-577-8211;* or **circle 101.**

Better measurements—free

One of the many problems faced by microwave and RF engineers is determining and maintaining the integrity of their measurements. What with reflections and losses occurring at each and every connection, the errors mount up, but to what extent, it is not always easy to determine.

Now Anritsu Wiltron Sales Co. is offering a free software program for improving the quality of scalar return-loss measurements. It calculates the return-loss uncertainty due to cascaded errors based on data (like directivity, test port match, and insertion loss) entered by the user. It can also take into account the effects of adapters.

Both DOS- and Windows-based versions are available. There is no charge for either. *Contact: Anritsu Wiltron Sales Co., 685 Jarvis Dr., Morgan Hill, CA 95037; 800-230-AWSC; fax, 408-778-0239;* or **circle 102.**

Your first fuzzy system

For many, the highest hurdle in building a fuzzy system is the first one—getting started. Once they have a more or less working model in place, most new users probably know at least one way to tune it. But choosing the initial rule base and fuzzy sets can be a problem.

That is where Rule Maker from HyperLogic Corp. can help. An add-on to the company's CubiCalc line of fuzzy logic development tools, Rule Maker generates fuzzy systems from data supplied to it by the user.

EEs' tools & toys

Because no single approach is best for all systems, Rule Maker incorporates several. For cases in which the available data is too sparse for a neural network approach to work, Rule Maker can choose among its other approaches, including statistical, analytic, and heuristic methods.

According to the company, almost any situation is covered by one of the methods incorporated in the product. Rule Maker can create systems with up to nine input variables and three output variables. The introductory single-copy price of Rule Maker is $195 in North America and $250 elsewhere. *Contact: HyperLogic Corp., 1855 East Valley Parkway, Suite 210, Escondido, CA 92027; 619-746-2765; fax, 619-746-4089; or* **circle 103.**

instrumentation

DMM is precise—and fast

In these days of low budgets and emphasis on value, an instrument that can double as a stand-alone precision benchtop digital multimeter and a fairly fast component for an automatic test system has special appeal. Such an instrument is Model 2000 from Keithley Instruments Inc., a 6-1/2-digit DMM that delivers 30 triggered readings per second over the IEEE-488 bus at full resolution. At lower resolutions, the meter is even faster, producing, for example, 1000 readings per second at 4-1/2 digits.


Surprisingly easy to use despite its 13 distinct functions, the Keithley Model 2000 DMM uses no menus. A few key presses set up any measurement on the 6-1/2-digit meter.

Whether standing alone or part of a system, the 2000 fairly oozes versatility. It has 13 built-in measurement functions: ac and dc voltage; ac and dc current; two-wire resistance; four-wire resistance; frequency; period; decibels; decibels referred to millivolts; temperature (supports J, K, and T-type thermocouples); continuity; and diode test.

To turn the meter into a small, stand-alone test system, there is a small back-panel slot into which a 10-channel scanner card or a nine-channel thermocouple scanner card may be plugged.

The Model 2000 has a basic 90-day voltage uncertainty of 0.002 percent of reading for dc and 0.05 percent for ac. For four-wire resistance, the basic 90-day uncertainty is 0.008 percent of reading.

The instrument is electronically protected against overloads of up to 1000 V across its input terminals and up to 1500 V from the high input terminal to ground. It sells for $995. *Contact: Keithley Instruments Inc., 28775 Aurora Rd., Cleveland, OH 44139; 216-248-0400; toll-free, 800-552-1115; or* **circle 104.**

literature

IEEE standards for 1995

Developing and disseminating industry standards is one of the IEEE's most important activities, so the availability of the Institute's *1995 Standards Products Catalog* should interest many readers. More than 700 IEEE electrotechnology standards publications are listed in the compendium, which is offered free of charge.

The catalog may be downloaded electronically in three ways:

- From the IEEE's electronic bulletin board system (BBS) at 908-981-0035.
- From the Internet, via the World Wide Web, at http//stds.ieee.org:70/0/pub/ieeestds.htm.
- From the Internet, by way of Gopher and FTP, at stdsbbs.ieee.org (IP address 140.98.1.11).

For a paper copy, **circle 105.**

new & noteworthy

- What are believed to be the industry's first **3-V silicon avalanche transient voltage suppressors** have been announced by ProTek devices, Tempe, Ariz. Designed and characterized specifically for 3.0/3.3-V applications, the devices have a peak power rating of 500 W for an industry-standard 8/20-μs pulse—a pulse with a front time, from zero to peak value, of 8 μs and a decay time, to 50 percent of peak value, of 20 μs. The parts have a theoretical response time of 10 ps, and a maximum clamping voltage of 6.5 V at 1 A. **Circle 106.**
- The 1995–96 **Test and Measurement Catalog and Reference Guide** produced by Keithley Instruments Inc., Cleveland, Ohio, includes comprehensive technical data, specifications, selection guides, and application information on the company's extensive line of test equipment and accessories. Among the instruments covered are digital multimeters with resolutions from 4-1/2 to 8-1/2 digits, electrometers, switching cards, scanner cards, and even an entire system for testing flash memories. The 256-page tome is offered free of charge. **Circle 107.**
- Sharp Electronics Corp., Camas, Wash., has introduced a **primary-side switching voltage regulator** that combines a power MOSFET and a switching control IC in a single TO-220 package. Its output device can sustain a maximum drain-to-source voltage of 500 V and a maximum drain current of 4.5 A. Its allowable dissipation varies from a low of 2 W (in free air with no heat sink) to 20 W (with a theoretical infinite heat sink). The Model PQ1PF1 regulator sells for $5.39 in hundred-piece lots. **Circle 108.**
- **A wideband (300-MHz) operational amplifier** that draws at most a mere 1 mA from a single 5-V supply has emerged from Analog Devices Inc., Wilmington, Mass. The AD8011 is aimed at applications in portable video equipment, communication systems, graphics workstations, document scanners, and data acquisition. It slews at 3500 V/μs and settles to within 0.1 percent in 25 ns. Its worst-case harmonic distortion is quoted at –62 dB at 20 MHz while driving a 150-Ω load. The AD8011 is priced at $1.95 in 1000-piece lots. **Circle 109.**

MICHAEL J. RIEZENMAN, Editor

Consultant: Paul A.T. Wolfgang, *Boeing Defense & Space Group*

The Product Profiles advertising section provides a monthly, distinctive focus on both new and commercially established products and services. They offer practical solutions for engineering and scientific professionals in today's fast-paced, rapidly changing high-tech environment.

Circle the corresponding number on the Reader Service Card.

CLASSIFIED EMPLOYMENT OPPORTUNITIES

The following listings of interest to IEEE members have been placed by educational, government, and industrial organizations as well as by individuals seeking positions. To respond, apply in writing to the address given or to the box number listed in care of *Spectrum* Magazine, Classified Employment Opportunities Department, 345 E. 47th St., New York, N.Y. 10017.

ADVERTISING RATES
Positions open—$40.00 per line, not agency-commissionable.
Positions wanted—$40.00 per line, a 50% discount for IEEE members who supply their membership numbers with advertising copy.

All classified advertising copy must be received by the 25th of the month, two months preceding the date of issue. No telephone orders accepted. For further information call 212-705-7578. IEEE encourages employers to offer salaries that are competitive, but occasionally a salary may be offered that is significantly below currently acceptable levels. In such cases the reader may wish to inquire of the employer whether extenuating circumstances apply.

Academic Positions Open

Texas A&M University: The Electrical Engineering Department expects to have several openings for tenure track faculty at all ranks. Applicants must have ■ Ph.D. degree or the equivalent or completion of all requirements by date of hire. For senior positions, applicants should have ■ proven record of scholarly contributions, and for junior positions, demonstrated potential for quality research and teaching is necessary. The salary is competitive and commensurate with qualifications and experience. Applicants are sought in the areas of computer engineering, microelectronics, power electronics, signal processing, and medical electronics. Applicants should send a complete resume, including names and addresses of three references to Dr. A.D. Patton, Department Head, Electrical Engineering Department, Texas A&M University, College Station, TX 77843-3128. Texas A&M University is an equal opportunity/affirmative action employer and actively seeks the candidacy of women and minorities.

Ghulam Ishaq Khan Institute of Engineering Sci■■■■ and Technology, Faculty of Electronic Engineering & Faculty of Computer Science invite applications for faculty positions at all levels. Applicants must have ■ Ph.D. from ■ recognized University with a strong commitment to teaching, research, and publications. The Institute offers nationally competitive salaries and generous fringe benefits. The applicants should submit ■ curriculum vitae with names of three references to the Rector, Ghulam Ishaq Khan Institute of Engineering Sciences and Technology, Topi, District Swabi, N.W.F.P. Pakistan. Fax # (92) 5372-71865. The Institute is an equal opportunity employer which does not discriminate based on sex, race, religion or ethnicity.

Post-Doctoral Research Fellow in Photonics: The Center for Photonics and Optoelectronic Materials (POEM) at Princeton University is seeking applications from qualified candidates for appointment as a Post-Doctoral Research Fellow to work on the design and growth of indium phosphide-based optoelectronic device structures by gas source molecular beam epitaxy. Prospective candidates should have a PhD in electrical engineering, materials science, physics or associated fields, and should have hands-on in-depth experience with MBE growth fabrication, and characterization of devices such as lasers, modulators, etc. The successful candidate will work on independent research projects, as well as lead and organize larger group activities involving graduate students at all levels of expertise. Appointments are for one year with the possibility of extension. Salary level depends on experience. Candidates should send their resume and three letters of reference to Prof. Stephen R. Forrest, ATC/POEM, E-Quad. J303, Dept. of Electrical Engineering, Princeton University, Princeton, NJ 08544. Princeton University is an Equal Opportunity Employer.

The University of Kansas Department of Electrical Engineering and Computer Science invites applications for a tenure-track faculty position in the remote sensing area to begin in August 1995. Applicants at the rank of assistant professor and associate professor will be considered and must have ■ Ph.D. in electrical engineering or physics. The successful candidate is expected to teach and supervise students both at the undergraduate and graduate levels and conduct research in remote sensing or RF/microwave engineering. Applicants with ■ Ph.D. in physics must have research experience in microwave remote sensing or RF/microwave engineering. Assistant professor candidates should have ■ high potential for both teaching and research. Applicants for the rank of associate professor should have a distinguished research record and a strong interest in educational programs. Applications, including resume, description of teaching and research interests, and the names and addresses of at least three references, should be sent to Professor Prasad Gogineni at EECS Department, 1013 Learned Hall, University of Kansas, Lawrence, Kansas 66045. Applications received until the position is filled will be considered. The University of Kansas is ■■ EO/AA employer.

The University of Cincinnati, Department of Electrical & Computer Engineering and Computer Science: Applications are solicited for a tenure track faculty position in Electrical and Computer Engineering starting January, 1995. The prospective faculty member should have an earned Ph.D. in electrical engineering or applied physics. Applicants with expertise in high speed optoelectronic device fabrication and characterization are sought. The faculty member will be involved in research and teaching at both undergraduate and graduate levels. The individual will collaborate with established research programs in the area of nano/optoelectronics. Facilities in the department include a complete microfabrication facility, specialized equipment for plasma and reactive ion etching, focused ion beam implantation, chemical vapor deposition, molecular beam epitaxy, laser optical characterization, etc. The Department offers MS/Ph.D. programs in electrical engineering, computer engineering, and computing sciences as well as an ABET fully-accredited undergraduate program in Electrical and Computer Engineering. The Department has 45 full-time faculty, 240 full-time graduate students, 400 undergraduate students. Curriculum vitae and the names of three references should be sent to: Prof. Peter B. Kosel, Interim Head, Department of Electrical & Computer Engineering and Computer Science, P.O. Box 210030, University of Cincinnati, Cincinnati, Ohio 45221-0030. The University of Cincinnati is an Affirmative Action/Equal Opportunity employer and encourages and welcomes applications from women and minorities.

Postdoctoral/Research Faculty in Theoretical, Computational, and Experimental Chemistry and Physics: We are looking for exceptionally able (1) theoretical/computational chemists or physicists with a strong background in quantum or classical dynamics, intense light-matter interactions, quantum control of chemical dynamics, or related areas, (2) experimentalists, particularly with a background in one or more of the following: ultrafast lasers, atomic and molecular beams, laser generated x-rays, charged particle beams, or x-ray physics. Current research interests in our group include (1) theoretical and experimental quantum control of chemical dynamics with femtosecond lasers, (2) development of multi-terawatt femtosecond lasers and their application to high field chemistry and physics, (3) ultrafast, short wavelength electron and x-ray diffraction as applied to imaging molecular quantum dynamics. For ■ description of current group activities and personnel see our World Wide Web site, http://www-wilson.ucsd.edu/ or send email with no text to "wilsjob@ucsd.edu". To apply, please send ■ cv to Prof. Kent R. Wilson, Department of Chemistry 0339, University of California, San Diego, La Jolla, CA 92093-0339. Affirmative Action/Equal Opportunity Employer.

Rice University, Department of Electrical and Computer Engineering invites applications for an Assistant Professor level, tenure track faculty position in the area of telecommunication and communication networks, to begin in August 1995. Applicants must have a doctorate in Electrical Engineering, or ■ closely related field. Rice University is ■ small private university with a strong commitment to excellence in both research and teaching. The ECE Department has extensive computing and laboratory facilities. The Department of Electrical and Computer Engineering has close ties and active collaboration with the Department of Computer Science and the Department of Computational and Applied Mathematics. Applicants should submit their resume, a summary of their research accomplishments, and the names of at least three references to the Chairman of the Department of Electrical and Computer Engineering, Rice University, P.O. Box 1892, Houston, TX 77251-1892. Rice University is an equal opportunity/affirmative action employer.

Philadelphia College of Textiles and Science - Computer Science: Assistant Professor. Tenure-track. Ph.D. in computer science or computer engineering required. We seek candidates with backgrounds in computer architecture or software engineering who are interested in research interactions with faculty in the fuzzy logic and neural networks areas. Responsibilities include teaching undergraduate and graduate courses, advising students and developing and conducting sponsored research programs. The science department

currently has strong research programs in fuzzy set theory and applications, high speed computing and computational mathematics. Computing environment includes multimedia PC and Macintosh clusters, VAX 8250, separate UNIX network, Silicon Graphics and DEC Alpha AXP workstations, and access to Cray C90 supercomputer. Submit letter of application, curriculum vitae, statement of teaching and research interests and names, addresses and telephone numbers of three professional references to Dr. Richard A. Nigro, Vice President for Academic Affairs, Philadelphia College of Textiles and Science, School House Lane and Henry Avenue, Philadelphia, PA 19144. Applications reviewed beginning March 20, 1995 until positions are filled. PCT&S is an Affirmative Action, Equal Opportunity Institution.

Dean of the College of Engineering: Applications are invited for the position of Dean of the College of Engineering at the University of Massachusetts Lowell. The appointment will commence June 1, 1995 or as soon as possible thereafter. The University: The James B. Francis College of Engineering at the University of Massachusetts Lowell traces its origins to 1895, with the founding of the Lowell Textile School. Through 100 years of growth and development, the fundamental purpose of the school has remained constant; to prepare men and women for their entrance into the engineering profession, providing the leading industries in our region with skilled technical professionals, and to foster new technologies and disseminate them to industry. The College: The College consists presently of seven departments: Chemical and Nuclear, Civil, Electrical, Engineering Technology, Mechanical, Plastics and Work Environment. It is also home to several interdisciplinary research centers and laboratories and will have substantial connections to the newly created Institute for Massachusetts Partnering and Commercialization of Technology (IMPACT). The College has several unique strengths, including plastics engineering and environmental/work environment programs. The Position: The primary role of the Dean of the College is to foster excellence in teaching, research and service by example and through the exercise of vision and leadership. He or she must demonstrate a commitment to quality undergraduate and graduate programs and ■ record of developing, planning and evaluating these programs in accordance with ABET guidelines. In addition, he or she will also contribute to the development of new programs as part of an engineering - applied science - management continuum and to initiatives designed to recruit and retain minorities and women. To expand the College's already strong relationship with industry, the Dean must demonstrate the ability to represent the College effectively in interactions with the public and private sectors and to articulate the College's goals and plans to ■ variety of constituencies. Ultimately, the Dean will guide the College toward meeting the University's goal: that each department in the College be ranked in the top quartile for engineering schools. Qualifications: The Dean must have a distinguished academic and research record and experience and knowledge of the national research and funding environment, as well as ■ record of excellence in academic administration. Salary: The salary is highly competitive with excellent fringe benefits. The Application: Screening of applicants will begin mid-January and continue until the position is filled. The application should consist of: i) ■ letter of application including discussion of educational and administrational philosophy and vision; ii) a curriculum vitae; iii) official copy of doctoral transcript; iv) ■ list of 6 references (names, addresses and telephone numbers). Applications must be addressed to: Dr. Janice M. Stecchi, Co-Chair, Search Committee for Dean of College of Engineering, College of Health Professions, University of Massachusetts Lowell, One University Avenue, Lowell, MA 01854; Tel: (508) 934-4461; Fax: (508) 934-3006; EMail: StecchiJ@woods.uml.edu The University of Massachusetts Lowell is an Equal Opportunity/Affirmative Action, Title IX, H/V, ADA 1990 employer.

Dean, Engineering and Energy, West Virginia University: WVU is the land-grant institution in the State of West Virginia with 23,000 students in fifteen colleges and schools located in Morgantown. The University is considering combining the existing College of Engineering and College of Mineral and Energy Resources. The combined college will enroll 1300 undergraduate and 700 graduate majors, awarding BS, MS, and Ph.D. degrees across a full spectrum of programs. The colleges now employ 110 full-time faculty and approximately 100 staff, and have over $13 million in external research funding each year. Candidates should submit ■ letter of application; curriculum vitae; and the names, addresses and telephone numbers of at least four references. Screening of the applications will begin April 1, 1995 and will continue until the position is filled. Applications and nominations should be directed to: George A. Hedge, Ph.D., Search Committee for Dean of Engineering and Energy, West Virginia University School of Medicine, Research and Graduate Studies, 2267 Health Sciences South, P.O. Box 9104, Morgantown, WV 26506-9104, Telephone: (304) 293-7206. West Virginia University is an Equal Opportunity, Affirmative Action Employer and does not discriminate on the basis of race, color, religion, sex, age, marital status, disability, veteran status, national origin, or sexual orientation. The University attempts to be responsive to dual career couples.

Electrical Engineering - Assistant Professor: The Electrical Engineering Department at Cleveland State University is seeking applications for a tenure track faculty position at the assistant professor level in the Computer Engineering area. Minimum qualifications: Ph.D. in Computer Engineering, ability to conduct independent research and to teach undergraduate and graduate courses in Computer Engineering and Electrical Engineering. Preferred candidates will also have teaching and industrial experience and publications in Computer Engineering. Full job description on request. Deadline: April 1, 1995 or when filled. Starting Date: September 15, 1995. Send resume and names of three references to: Dr. Pong P. Chu, Chair of Search Committee, Electrical Engineering Department, Cleveland State University, E. 24th & Euclid Ave., Cleveland, OH 44115. Equal opportunity employer, m/f/d. CSU provides reasonable accommodation for individuals with disabilities.

University of Miami, Department of Electrical and Computer Engineering invites applications for ■■ anticipated tenure-track position in the area of electro-optics. The position will be available in August 1995, and the academic rank will depend upon the qualifications of the successful candidate, including the possibility of an endowed chair. Applicants must possess an earned doctoral degree, be able to teach undergraduate courses in electronics, and show a strong record/commitment to graduate teaching and funded experimental research in

CLASSIFIED EMPLOYMENT OPPORTUNITIES

electro-optics. Possible areas of interest include optoelectronics, integrated optics, and lasers. The College of Engineering encourages interdisciplinary research, and candidates interested in biomedical applications of electro-optics are particularly welcome. The University is located in beautiful Coral Gables, a suburb of Miami, FL. Applications should be sent with the names of three references to: Dr. Tzay Y. Young, Chairman, Department of Electrical and Computer Engineering, P.O. Box 248294, University of Miami, Coral Gables, Florida 33124. The University of Miami is an equal opportunity/affirmative action employer.

The Hong Kong Polytechnic University (formerly Hong Kong Polytechnic) invites applications for the following post: Department of Electronic Engineering - Professor/Associate Professor in Computer Systems Software and Communication Engineering. The appointee will be required to teach and conduct research up to postgraduate level in one or more of the following areas: Distributed Processing and Systems, Operating Systems and Concurrent Programming, Software Engineering, Data Structure and Database Management Systems, Functional and Object-oriented Design, High Performance Computer Architecture/Intelligent Systems, Neural Networks and Fuzzy Theory/Modern DSP Applications, Speech/Digital TV and HDTV, Mobile Communication and RF Design, High Speed Networks, Fibre Optics, Telecom Software and Networking, Electronic Circuits and Design. The appointee is expected to engage in research planning, research direction and to supervise PhD students. Applicants should have (a) a PhD degree; (b) ■ strong record in research and publication and research leadership; (c) good capability in teaching; (d) contribution in professional service to the community; and (e) preferably some industrial experience. For appointment at Professor level, ■ distinguished record of research and scholarship is required. Salary and Conditions of Service - Professor: HK$669,360 - HK$889,260 per annum. Associate Professor: HK$641,580 - HK$861,900 per annum. (US$1 = HK$7.8 as at 9 January 1995) Initial appointments ■■ normally made on a fixed term gratuity-bearing contract of two years, at the end of which re-engagement is subject to mutual agreement. Other benefits include leave, subsidized housing, medical and dental schemes, and children's education allowance. Application: Application including curriculum vitae and names of three referees should be sent to the Personnel Office, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong before April 15, 1995. [Fax (852) 2764 3374, E-mail GSSTAFF@HKPCC.HKP.HK].

The Osteoporosis Research Group (Department of Radiology, Skeletal Section) of the University of California, San Francisco is seeking ■ computer scientist (Ph.D. level) to further the development of image processing in quantification of bone mineral density, and bone microstructure for osteoporosis research studies. Principal image processing package is Advanced Visual Systems (AVS), utilized for the development of image processing tools to quantify bone density and structure acquired via traditional radiographic technique, magnetic resonance imaging, and two- and three-dimensional tomography. Documentation skills are necessary for presenting these tools for general use. In detail, the work will involve study of image enhancement and registration algorithms; study of segmentation methods

and application of these to images; development of texture analysis tools; participation in AVS meetings organized to develop and improve personal modules of the participants, and define them for general use; develop (and simplify for general use) image processing algorithms for high resolution magnetic resonance images; and define demonstrations for image processing algorithms on AVS package to represent the work done by the Osteoporosis Research Group. Required skills, knowledge and abilities: Ph.D. in Computer Science; familiarity with image processing techniques, preferably with Advanced Visual Systems software package; and familiarity with UNIX (and VAX/VMS) operating systems. Send resume to Harry K. Genant, M.D., Professor of Radiology, Medicine, and Orthopaedic Surgery, Box 0628, Dept. of Radiology, University of California, San Francisco, CA 94143. Equal Opportunity Employer. Minority groups, women and handicapped individuals are encouraged to apply.

Rensselaer Polytechnic Institute: The Department of Electrical, Computer and Systems Engineering invites applications for a tenure-track position at the Assistant Professor level. The specific area of interest is computer engineering with an emphasis on computer communications networks. This new faculty position is part of a major Engineering Renaissance at Rensselaer initiative designed to position Rensselaer for technological leadership in the 21st century. The ECSE Department is the largest academic unit at Rensselaer and has a rich tradition for both research and education. ECSE is seeking to add top quality faculty who bring innovative approaches to modern areas of research and who can effectively participate in a campus-wide educational initiative in Interactive Learning. ECSE has major programs in multimedia communications and signal processing; robotics, intelligent control and manufacturing; integrated electronics and electronics manufacturing; and energy systems which contribute to [illegible] dynamic research environment. In addition to the extensive research facilities of the department, there are excellent opportunities for faculty to participate in interdisciplinary research centers including the Center for Image Processing Research, the Center for Integrated Electronics and Electronics Manufacturing, the New York State Center for Advanced Technology in Automation, Manufacturing and Robotics, the Scientific Computation Research Center and the Center for Composite Materials and Structures. There are also close links between ECSE and the Department of Computer Science. New faculty are eligible for special career start-up arrangements including summer support, equipment, graduate student support and reduced teaching loads to encourage the development of successful research programs. Applications and/or requests for further information should be directed to: Dr. William C. Jennings, Department Head, Electrical, Computer and Systems Engineering, Rensselaer Polytechnic Institute, Troy, NY 12180-3590. Dr. Jennings may be reached by phone at (518) 276-6316 or electronically at jennings@ecse.rpi.edu. Rensselaer is an affirmative action/equal opportunity employer and specifically encourages applications from women and minorities.

Hallym University in Korea: The Department of Electronic and Control Engineering invites applications for faculty positions. Areas of interest include VLSI Design/CAD, Control Systems and Robotics, Neural Networks, Digital/Analog Circuits, Microprocessors, and Signal Processing, all with emphasis on applications. Industrial/Research experience and/or publication in major journals are a plus. Applications will be accepted until 3 or 4 positions [illegible] filled. For more information, e-mail: gmoon@sun.hallym.ac.kr

Sprint Eminent Scholar Chair Professorship in Electrical Engineering [illegible] Florida A&M University and Florida State University, College of Engineering: The FAMU/FSU College of Engineering seeks nominations and applications for the newly endowed Sprint Eminent Scholar Chair professorship in electrical engineering. The Sprint professor will take an active leadership role in building both the undergraduate and graduate programs and in developing new research initiatives in electrical or computer engineering. Applicants should hold a doctoral degree in Electrical or Computer Engineering and be eligible for a tenured full professorship as demonstrated by experience and excellence in both teaching and research. Candidates should have [illegible] record of distinguished scientific achievement in one or more of the following areas: electro-magnetics, electronic materials and devices, digital signal processing, telecommunication, computer engineering and optoelectronics. The ability to engage in collaborative research and to motivate and inspire students are required attributes. The candidate can expect involvement in the National High Magnetic Field Laboratory which is located next to the College of Engineering and has interests in the development and application of high field magnets in a variety of engineering applications and RF Electronics as applied to Magnetic Performance Spectroscopies. The department presently has 16 full time faculty and is expected to grow to about 25 full time faculty within the next few years. Current faculty expertise is in the areas of electro-magnetics, digital signal processing, magnetic materials, opto-electronics, communications and high performance computing. The department enrolls 600 undergraduates and has [illegible] growing graduate program with 60 full time students in M.S. and Ph.D programs. Applications and nominations should be submitted with a statement of interest and goals, [illegible] vita, and names of five references to: Prof. Anjaneyulu Krothapalli, Chair, Sprint Eminent Scholar Chair Search Committee, FAMU/FSU College of Engineering, P.O. Box 2175, Tallahassee, Florida 32316. Review of applications will close April 15, 1995. The position will be filled by August 1995. The Florida A&M and Florida State Universities are Equal Opportunity/Affirmative Action employers that encourage applications from minority and women and comply with the Americans with Disabilities act. They are public record agencies pursuant to Chapter 119, Florida Statutes.

Boston University Faculty Position: The Computer Science Department at Boston University's Metropolitan College serves professionals in the Greater Boston area with part-time undergraduate and graduate degree programs. These programs are among the largest of their kind in the Northeast. The department seeks an instructor with [illegible] technical interest in Networks and Data Communications, beginning in September, 1995. The faculty member will also be expected to spend a significant amount of time advising prospective and current graduate computer science students. Both academic background and industry experience will be considered. A Master's degree, at a minimum, and excellent teaching skills are required. Please send applications, and arrange for three letters of accommodation to be sent to Dr. Eric Braude, Chair Boston University Metropolitan College, 755 Commonwealth Avenue, Room B4, Boston, MA 02215. Applications will be considered until the position is filled.

University [illegible] Tromsø, Norway: The Institute of Mathematical and Physical Science invites applications for two tenured positions as Associate Professor in Electrical Engineering/Applied Physics. The applicants should have [illegible] background in [illegible] or more of the fields remote sensing, signal/image processing, pattern recognition, measurement technique, micro wave technique, and/or electronic circuit design (preferably analog ASIC). Application deadline is April 1. Applications should be submitted to: Institute of Mathematical and Physical Science, University of Tromsø, 9037 Tromsø, Norway. For more information about the positions and about how to apply for them, please contact Professor Einevoll (phone: +47 776 45165, fax: +47 776 45580, E-mail: gaute@phys.uit.no) or Professor Eltoft (phone: +47 776 45184, fax: +47 776 45580, E-mail: pcte@phys.uit.no)

North Carolina State University, Center for Advanced Electronic Materials Processing - Post-Doctoral Research Position: This NSF Engineering Research Center is an interdisciplinary academic/research program involving faculty, researchers and students from the Departments of Electrical and Computer Engineering, Materials Science and Engineering, Physics, Chemical Engineering and Mechanical Engineering. The goal is to develop processing technology and equipment capability for the fabrication of advanced submicron device structures. Emphasis is on the development of process module clusters for carrying out multiple process steps in an in-situ environment. A post-doctoral research position is available for qualified applicants. This includes supervising students on single wafer processing using RTCVD, RPECVD, RT selective epitaxy and plasma etching. An earned doctorate or equivalent industrial research experience is required. Interested applicants should send resumes and the names, addresses and telephone numbers of three references by April 30, 1995, to: Dr. J.R. Hauser, Center for Advanced Electronic Materials Processing, North Carolina State University, Box 7920, Raleigh, North Carolina 27695. North Carolina State University is an Affirmative Action, Equal Opportunity Employer.

Dean, Erik Jonsson School of Engineering and Computer Science: The University of Texas at Dallas invites nominations and applications for appointment to the position of Dean of the Erik Jonsson School of Engineering and Computer Science and concurrent appointment to the Lars Magnus Ericsson Chair in Electrical Engineering. The University, a Carnegie Foundation "Doctoral University I," emphasizes internationally competitive research by its faculty, selective student admissions, [illegible] rigorous curriculum, and a high level of interaction with and service to the multinational technologically sophisticated and managerially intensive businesses and industries headquartered in the region. With [illegible] current enrollment of approximately 4500 undergraduates and 4000 graduate students, U.T. Dallas is situated on a spacious 500 acre campus 20 miles north of the central Dallas business district, in the heart of the "Telecom Corridor" complex of residential suburbs and corporate office parks. The Erik Jonsson School offers doctoral and bachelor degrees in Electrical Engineering and in Computer Science, together with masters degrees in those fields and in Engineering Science. Approxi-

ng and industrial experience t not required. Duties include s and associated laboratories Engineering Science - Sysncentration (instrumentation, nd machinery, control theory, l electronics.) Screening of start April 17, 1995 and consition is filled. Salary and bentive. Send letter of application, nes of three references to Dr. ead, Department of Engineerntana Tech, 1300 West Park 59701-8997. EEO/AAE

ch Engineer, University of eley: Department of Materials gineering. Duties include the nicrofabrication processes for nd microfilters, and assistance on of students doing research oject. Requirements: PhD in eering or related fields and in microfabrication, with prefMS. Salary range: $54,300-ding on qualifications. Initial 7 months, starting as soon as ointment subject to the availural funds. Application dead95. Send CV and three referlauro Ferrari, 733 Davis Hall, fornia, Berkeley 94720.

and should be addressed to: Office of the Provost, Att: Abby Kratz, The University of Texas at Dallas, P.O. Box 830688 MS-AD23, Richardson, Texas 75083-0688. Review of applications will begin on February 27, 1995 and continue until the position is filled. The University of Texas at Dallas is an Equal Opportunity, Affirmative Action employer and strongly encourages applications from candidates who would enhance the diversity of the University's faculty and administration.

University of Pittsburgh: The Department of Electrical Engineering invites applicants for a full-time tenure track faculty position at the Assistant or Associate Professor level beginning September 1995. The areas of interest are Computer Engineering and Control. Preference will be given to applicants with research expertise in Computer Architecture, Parallel Processing, Computer Vision, Computer Control, Sensors/Actuators; particularly those with applications in Bioengineering or Manufacturing. Candidates must possess an earned PhD degree and be committed to an integrated program of teaching and research. The department consists of 31 faculty supervising 300 undergraduate and 180 graduate students. Applicants should submit a resume, a brief statement of research and teaching interests and the names of five references to: Dr. Marwan Simaan, Chairman, Department of Electrical Engineering, 348 Benedum Hall, University of Pittsburgh, Pittsburgh, PA 15261. Tel: (412) 624-8002. In order to receive full consideration, applications must be received before April 15, 1995. The University of Pittsburgh is an Affirmative Action/Equal Opportunity Employer.

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tions, the C/C++ programming language, and X-Windows is necessary. Image and signal processing experience is desirable. Previous experience with magnetic resonance instrumentation and system administration is preferred but not required. Salary will be commensurate with experience. A resume and three letters of recommendation should be sent to: John P. Strupp, Center for Magnetic Resonance Research, University of Minnesota Medical School, 385 East River Road, Minneapolis, MN 55455. Deadline for receipt of applications is March 31, 1995. The University of Minnesota is an equal opportunity educator and employer.

University of Massachusetts, Department of Electrical and Computer Engineering: The Department of Electrical and Computer Engineering at the University of Massachusetts at Amherst invites applications for ■ tenure-track position in electrical and computer engineering as an associate or full professor. We are seeking candidates in the following areas: (1) wireless telecommunication networks, (2) semiconductor (e.g., VLSI ICs, MCMs) manufacturing, and (3) optical remote sensing. Rank and salary will be commensurate with qualifications. Applicants must have an earned doctorate and a proven record of research funding. Preference will be given to candidates with experimental/industrial experience. The search will continue until the position is filled. Send a resume and names of at least three references to Chair, Search Committee, Department of Electrical and Computer Engineering, University of Massachusetts, Amherst, MA 01003. The University of Massachusetts is an Affirmative Action/Equal Opportunity employer.

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Harvard University: We invite applications from candidates at all levels for a faculty position in Electrical Engineering. Individuals with interests in the area of electronics or communications are sought. Candidates should have an interest in design and fabrication at the device or systems level and have ■ Ph.D in Electrical Engineering, Computer Engineering, or a related discipline. Responsibilities include teaching in the AB., S.B., and Ph.D programs and having ■ strong research commitment. Applicants should submit ■ curriculum vitae and the names, addresses (including email) and telephone numbers of three references to the EE Search Committee, Pierce Hall 217, Harvard University, 29 Oxford Street, Cambridge, MA 02138. Applications should be received by April 30, 1995. Harvard is an Equal

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Rensselaer Polytechnic In ment of Electrical, Compu neering invites applicatio position at the Assistant specific area of interest is with an emphasis on com networks. This new facult major Engineering Renais initiative designed to po technological leadership in the 21st century. The ECSE Department is the largest academic unit at Rensselaer and has a rich tradition for both research and education. ECSE is seeking to add top quality faculty who bring innovative approaches to modern areas of research and who can effectively participate in a campus-wide educational initiative in Interactive Learning. ECSE has major programs in multimedia communications and signal processing; robotics, intelligent control and manufacturing; integrated electronics and electronics manufacturing; and energy systems which contribute to a dynamic research environment. In addition to the extensive research facilities of the department, there are excellent opportunities for faculty to participate in interdisciplinary research centers including the Center for Image Processing Research, the Center for Integrated Electronics and Electronics Manufacturing, the New York State Center for Advanced Technology in Automation, Manufacturing and Robotics, the Scientific Computation Research Center and the Center for Composite Materials and Structures. There are also close links between ECSE and the Department of Computer Science. New faculty are eligible for special career start-up arrangements including summer support, equipment, graduate student support and reduced teaching loads to encourage the development of successful research programs. Applications and/or requests for further information should be directed to: Dr. William C. Jennings, Department Head, Electrical, Computer and Systems Engineering, Rensselaer Polytechnic Institute, Troy, NY 12180-3590. Dr. Jennings may be reached by phone at (518) 276-6316 or electronically at jennings@ecse.rpi.edu. Rensselaer is an affirmative action/equal opportunity employer and specifically encourages applications from women and minorities.

Hallym University in Korea: The Department of Electronic and Control Engineering invites applications for faculty positions. Areas of interest include VLSI Design/CAD, Control Systems and Robotics, Neural Networks, Digital/Analog

interests in the development and application of high field magnets in a variety of engineering applications and RF Electronics as applied to Magnetic Performance Spectroscopies. The department presently has 16 full time faculty and is expected to grow to about 25 full time faculty within the next few years. Current faculty expertise is in the areas of electro-magnetics, digital signal processing, magnetic materials, opto-electronics, communications and high performance computing. The department enrolls 600 undergraduates and has a growing graduate program with 60 full time students in M.S. and Ph.D programs. Applications and nominations should be submitted with a statement of interest and goals, a vita, and names of five references to: Prof. Anjaneyulu Krothapalli, Chair, Sprint Eminent Scholar Chair Search Committee, FAMU/FSU College of Engineering, P.O. Box 2175, Tallahassee, Florida 32316. Review of applications will close April 15, 1995. The position will be filled by August 1995. The Florida A&M and Florida State Universities are Equal Opportunity/Affirmative Action employers that encourage applications from minority and women and comply with the Americans with Disabilities act. They are public record agencies pursuant to Chapter 119, Florida Statutes.

Boston University Faculty Position: The Computer Science Department at Boston University's Metropolitan College serves professionals in the Greater Boston area with part-time undergraduate and graduate degree programs. These programs are among the largest of their kind in the Northeast. The department seeks an instructor with a technical interest in Networks and Data Communications, beginning in September, 1995. The faculty member will also be expected to spend a significant amount of time advising prospective and current graduate computer science students. Both academic background and industry experience will be considered. A Master's degree, at a minimum, and excellent teaching skills are required. Please send applications, and arrange for three letters of accommodation to

Engineering. The goal is to develop processing technology and equipment capability for the fabrication of advanced submicron device structures. Emphasis is on the development of process module clusters for carrying out multiple process steps in an in-situ environment. A post-doctoral research position is available for qualified applicants. This includes supervising students on single wafer processing using RTCVD, RPECVD, RT selective epitaxy and plasma etching. An earned doctorate or equivalent industrial research experience is required. Interested applicants should send resumes and the names, addresses and telephone numbers of three references by April 30, 1995, to: Dr. J.R. Hauser, Center for Advanced Electronic Materials Processing, North Carolina State University, Box 7920, Raleigh, North Carolina 27695. North Carolina State University is an Affirmative Action, Equal Opportunity Employer.

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mately 30 tenured/tenure-track faculty, with strong support from full-time and part-time lecturers, provide instruction in the School's programs, which each award approximately 50 bachelors and 50 masters degrees annually, together with several doctoral degrees. The Dean is the administrative and academic leader of the School, having broad responsibilities for academic policies and procedures, curriculum development, budget management, long-range planning, and the recruitment, development and retention of an outstanding and collegial faculty. The Dean represents the School internally and externally and provides the initiative and leadership for continued development of the strong, synergistic collaborations with individuals and organizations from the high-technology business sector which are a defining feature of the U.T. Dallas mission. The Dean must have outstanding abilities in communication and leadership, as demonstrated in significant administrative positions; must have a record of accomplishment appropriate for a tenured full professorship in the School of Engineering and Computer Science; must have a demonstrated commitment to equity and diversity, and the commitment to and enthusiasm for leading the School to even greater levels of productivity and achievement in education and research and for enhancing contributions of the School to the continued technological and economic development of the region and the nation. Applications should include a statement of interest, a full professional resume, and the names, addresses and telephone numbers of at least three references and should be addressed to: Office of the Provost, Att: Abby Kratz, The University of Texas at Dallas, P.O. Box 830688 MS-AD23, Richardson, Texas 75083-0688. Review of applications will begin on February 27, 1995 and continue until the position is filled. The University of Texas at Dallas is an Equal Opportunity, Affirmative Action employer and strongly encourages applications from candidates who would enhance the diversity of the University's faculty and administration.

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Research Fellow - MR Software: The Department of Radiology, University of Minnesota Medical School is seeking a full-time software engineer to be employed as a Research Fellow at the Center for Magnetic Resonance Research. The responsibilities of the position are: 1) Development and documentation of GUI and processing software for the analysis and display of MR images and spectra, 2) System administration of UNIX workstation/Macintosh network. Applicants must have a MS degree in electrical engineering or computer science, and have had extensive computer programming training. Experience with UNIX workstations, the C/C++ programming language, and X-Windows is necessary. Image and signal processing experience is desirable. Previous experience with magnetic resonance instrumentation and system administration is preferred but not required. Salary will be commensurate with experience. A resume and three letters of recommendation should be sent to: John P. Strupp, Center for Magnetic Resonance Research, University of Minnesota Medical School, 385 East River Road, Minneapolis, MN 55455. Deadline for receipt of applications is March 31, 1995. The University of Minnesota is an equal opportunity educator and employer.

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Assistant Research Engineer, University of California, Berkeley: Department of Materials Science and Engineering. Duties include the development of microfabrication processes for microcapsules and microfilters, and assistance in the coordination of students doing research related to the project. Requirements: PhD in Electrical Engineering or related fields and prior experience in microfabrication, with preference to MEMS. Salary range: $54,300-$68,800, depending on qualifications. Initial appointment for 17 months, starting as soon as possible. Reappointment subject to the availability of extramural funds. Application deadline: April 15, 1995. Send CV and three references to: Prof. Mauro Ferrari, 733 Davis Hall, University of California, Berkeley 94720.

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CLASSIFIED EMPLOYMENT OPPORTUNITIES

Opportunity/Affirmative Action employer and encourages applications from women and members of minority groups.

The Department of Electrical Engineering, University of Pennsylvania, is inviting applications for one faculty position in the area of Modern Digital Signal Processing and Communications. The appointment will likely be at the assistant professor level, although exceptionally qualified applicants may be considered for other levels. Candidates with expertise in one or more of the following or closely related areas of research interest are invited to apply for this position: video processing, coding and transmission; signal processing theory, architectures, implementations, and applications; wireless communications. The successful applicant will be able to teach a range of courses at both the undergraduate and graduate levels, will have an excellent record of research accomplishments and will engage in funded research projects in cutting-edge areas in signal processing. Applicants are invited to send a complete resume with names of at least three references to: Chairman, Department of Electrical Engineering, Moore School, University of Pennsylvania, Philadelphia, PA 19104. Applications arriving after April 1, 1995 are not assured of receiving consideration.

Industrial Technology Instructor: Qualifications - 2000 hours work experience in industry, prefer recent experience. Teaching experience preferred. Bachelor's required, Master's preferred. Send letter, resume, & college transcripts by 4/14/95 to: Duane K. Kessler, Kaskaskia College, 27210 College Road, Centralia, IL 62801.

Associate Scientist - Center for Nondestructive Evaluation, Iowa State University: The Center for Nondestructive Evaluation at Iowa State University is seeking an Associate Scientist to develop and implement a research program applying signal and image processing techniques to x-ray and other nondestructive evaluation methods. Position requires a Ph.D. in electrical engineering or related field with two years of related research experience (may be concurrent with pursuit of degree). Experience must include x-ray image processing techniques, i.e., POD, image digitization and enhancement. Salary of $37,422 minimum, plus benefits. Send cover letter, resume, plus the names and addresses of three references to: Ames Laboratory/IPRT Personnel Office, 105 TASF, Iowa State University, Ames, IA 50011. Application deadline of April 15, 1995. An EEO/AA employer.

BellSouth Eminent Scholar's Chair in Computer Engineering and Communications: The Department of Electrical Engineering at the University of Florida invites nominations and applications for an endowed, chaired professorship in the general field of computers and communications. The Department of Electrical Engineering is the largest department in the University of Florida with about 425 undergraduates (junior and senior year only) and about 325 graduate students. The department is ranked 22 from about 260 Electrical Engineering undergraduate programs. There are eleven IEEE Fellows and two members of the National Academy of Engineering on the Electrical Engineering Faculty. There is presently one Eminent Scholar who holds the endowed chair in Microelectronics. For the BellSouth Chair we seek a researcher and teacher of great distinction. Proceeds from an endowment and additional resources will provide an environment commensurate with the excellence of the person sought. Nominations and applications should be sent to Professor Stanley Su, who co-chairs the BellSouth Chair Search Committee, Department of Electrical Engineering, 470 CSE, University of Florida, Gainesville, FL 32611-6125. Telephone 904/392-2693 or 904/392-2680; Fax 904/392-0044; email su@cis.ufl.edu. The application deadline is June 1, 1995. The University of Florida is an Affirmative Action Employer, and women and minorities are encouraged to apply. According to Florida law, applications and meetings regarding applications are open to the public upon request.

Government/Industry Positions Open

Project Electrical Engineer Wanted - Must have 5+ years exp. in design with Consulting Firm. Mail resume to: J.E. Connelly - CS Associates-P.O. Box 30926-Tucson, AZ 85751-0926. 602-327-7999

Senior Research Engineer: 40 Hours/week; 8:00 a.m. - 5:00 p.m.; $63,600/year. Job requires Ph.D. in Electrical Engineering and 18 months experience in Job Offered or as Controls Engineer. Job also requires: 1) Ph.D. dissertation in the area of adaptive control; 2) 2 journal publications in the area of adaptive control; 3) 1 journal publication in the area of digital signal processing; 4) Experience must include experience developing and implementing real-time engine controls; 5) Experience must include experience using computer-aided control systems design software; and 6) Experience must include experience designing and analyzing electronic engine control and diagnostics algorithms. Any experience requirements may be met concurrently during the same 18 month period. Job duties: Conduct research in automotive engine controls. Develop concepts and evaluate model-based adaptive algorithms for transient air-fuel ratio control and powertrain diagnostics. Recommend and initiate research and development plans on projects related to engine controls and diagnostics. Communicate research results effectively both orally and in writing to managers, researchers, and divisional customers. Interact closely with divisional customers and partners to meet project objects. Develop dynamic powertrain models for control systems analysis and design. Qualified applicants should send resume and verification of requirements to: 7310 Woodward, Room 415, Detroit, MI 48202. Reference #17795. Employer paid advertisement. An equal opportunity employer.

Engineer, Senior: Develop high efficiency cellular transmission methods for digital signals, analyze and simulate high spectral efficiency modulation and coding techniques in the cellular environment. Min. Ph.D. (Electrical Engineering) plus 1 yr. exp. or M.Sc. (Electrical Engineering) plus 5 yrs. exp. Requirements: Background in communication theory/adaptive signal processing/cellular networks. In-depth understanding of modulation and coding requirements for fading terrestrial channels. Job site/interview: San Diego, CA. Salary: $62,000/yr. 40 hrs/wk. Send this ad and your resume to Job #MLM 15957, P.O. Box 290605, Sacramento, CA 95826-9605.

Senior Design Engineer: Battery Industry. Western Regional battery and custom plastics mfr. announces a need for an advanced technical specialist with significant industry experience. Responsibilities include: Plan and execute new product devlpt of custom and smart battery packs. Develop capability to design, develop and manufacture battery chargers. Requirements: Tech degree, preferably advanced, 10-15 years product devlpt and/or project mgt and/or applications engrg experience in battery packs, smart packs and/or battery chargers; AutoCAD 12.0 proficiency. Preferences: experience in DFM&A, FMEA, GD&T, SPC and DOE; known professional standing in the battery/battery pack industry (i.e., patents, articles, etc.); second language, preferably Pacific Rim. Excellent opportunity to play a critical role with a rapidly growing company. Job location: Portland, Oregon metro area. Send resume to: Engineering Manager, P.O. Box 584, Beaverton, OR 97075.

Software Engineer needed to write, design and implement software for mortgage lending industry using all functions of the Borland C++ Version 3 professional software package, Make and Polytron's PVCS, as well as third party libraries for specific functions. Perform system builds specializing in data communications and financial calculations. Responsible for supervision of 2 - 4 software engineers. Must have: Bachelor's Degree in Computer Science and 1 year experience writing financial software, including methodology research, implementation, testing and documentation of financial software systems using all functions of the Borland C++ Version 3 professional software package, Make, and Polytron's PVCS. Must also have Bachelor's Degree in Business Administration with emphasis on finance or 2 years experience working with the mortgage loan industry. Experience may be gained concurrently. Salary: $42,000/year; 40 hours/week in Kirkland, WA. Send resume by 3/31/95 to: Job Order #471733; Employment Security Dept., E&T Div., PO Box 9046, Olympia, WA 98507-9046.

Engineering Business Consultant: Spprt autmtn projs at cust sites & meet integrtn/autmtn proj sched reqs, prepare & review functnl specs, matls (trng manls, instl manls, etc), desgn docs & test plans. Code enhancements, correct prblms while wrkg in C, TCP/IP, & SQL in VMS environ, provide timely & relevant status reports of projs to mgmt, ensure accuracy & qlty of all user deliverables, coordinate activities between cust & vendors. Min 40/wk. $45,000/year. Reqs: M.S. in Industrial Engineering with specialization in Mfg. & Automation & 2 yrs. exp. in job offered or 2 yrs exp working with process control system in mfg. envrnment. Spec. Reqs: 2 yrs prior exp must incl 1 yr tsting & validation of factry automation systems including Automated Material Handling Systems. Proficiency in writing SW in "C" & Pascal langs in VMS mfg. envrnmnt; knwldg of prgrmming SQL and TCP/IP protocols in VMS mfg. envrnmt; exp in devlpment & writing of intrnl techncl manls and specs.; willing to relocate and able to travel for extended periods of time. Job in Rio Rancho, NM. Qualfd applcnts send res to: NM Dept of Labor, P.O. Box 44276, Rio Rancho, NM 87174, Job Order No. 426503. Must have proof of legal auth to wrk in US. The comp is an Equal Opp employer & fully supports affirmative action practices.

Engineering Opportunities: GSE, Inc., a prominent electronics manufacturing company, is seeking several highly motivated individuals to assist in developing new product markets and product lines. Due to significant growth and establishment of the market potentials, we are now accepting applications for several posi-

tions in the Development Engineering and Test Engineering areas. Senior Project Engineers - We are seeking individuals to manage the development of several new product lines. Candidates must be capable of managing a small group of electrical and mechanical design engineers toward the development of microprocessor based smart transducers. Individuals must possess the following qualifications: Minimum of a Bachelor of Science Degree in Mechanical or Electrical Engineering with five to ten years experience and project management. Must be capable of developing new product specifications through interaction with end users and marketing contacts. Products developed will include microprocessors, strain gages, finite element analysis on metal transducer flexures, laser gyro, infra-red and radio frequency communications. Hardware/Software Engineers - GSE needs several Electrical Engineers capable of designing microprocessor hardware and software. Minimum of BSEE and BSEET with three years or more experience. Familiar with C, C++, Motorola and Intel processors, ACAD and Integraph. Transducer Design Engineers - GSE now has openings in strain gage transducer design. We are seeking an individual to develop flexure design, execute 3-D finite element analysis, and assist in developing test fixtures and calibration procedures. Minimum of BSME or BSMET with three years or more experience. Familiar with ACAD12 (3-D), Algor (with Hexagon), DOS, Windows, etc. A strong electrical background is preferred. We offer a competitive compensation package and an exciting growth environment for the right people. Please send your resume in confidence to: GSE, Inc., 23640 Research Drive, Farmington Hills, MI 48335-2621, Attention: Human Resources/EE.

Electronics Design Engineer for Dayton Area Equipment Mfr. Duties include development of software and hardware protocols for image processing systems used in electronic engraving system, analysis of user requirements to develop graphics user interfaces for cylinder composition software system, development of automatic manufacturing control algorithm for engraving procedure assisted by image processing system, and performance of concurrent programming in "C" language with following interprocess protocols. Position is also responsible for providing technical support for Chinese-speaking companies in the areas of installing and upgrading software, training users, and performing ongoing technical support and trouble shooting. Position requires travel to Asia for one-to-two week periods about three or four times per year. Requirements for this position include a Masters Degree in Mechanical or Electrical Engineering, the curriculum of which included courses in Digital Image Processing, Microcomputer Applications, Comp I/O Realtime, Advanced Computer Vision, Computer Communication Networks, and System Dynamic Analysis. The Master thesis must be in a topic related to Image Processing. Position also requires the ability to read, write and speak Chinese. No experience required. Hours are usually 8 a.m. to 5 p.m. Monday thru Friday (40 hours per week) with some overtime as required by project deadlines or customer demands. Rate of pay is $37,500 per year with no additional overtime compensation. Send two (2) resumes and cover letters (no calls) to: G. Maugans, JOB# 00823, Ohio Bureau of Employment Services, PO Box 1618, Columbus, OH 43216.

Senior Engineer/Architect (Electrical), Denver International Airport: The City & County of Denver is seeking qualified candidates to fill the position of Senior Engineer/Architect (Electrical) at Denver International Airport. Candidates must have a minimum of 3 years experience as an Electrical Engineer with qualifications in Engineering Planning, Design, Construction, Operation & Maintenance of large complex electrical/power systems in multi buildings and systems. Experience should include the following applications; Lighting Controls, Low & Medium Voltage Distribution, Low & High Voltage Systems in large physical plants, Conventional Buildings Systems, Energy Management, Life Safety Systems, and Distributed Control Systems. Full knowledge of the National Electrical Code. Computer literacy in the following desirable; Computer/PLC Control Networks, Microsoft Windows, MMI Software Packages, WordPerfect & Lotus. Must have understanding of other engineering disciplines and architecture as well as have a good working relationship with other engineering disciplines and construction trades. This position will function as the only Electrical Engineer in the Planning and Engineering Division of DIA. Airport facilities experience is preferred, but not required. Must have a Baccalaureate Degree with major course work in Electrical Engineering. Registration as a P.E. by the Colorado State Board of Registration for Professional Engineers at the time of application. Registration as a P.E. by another state will be accepted in lieu of this requirement, provided that the applicant must be registered by the State of Colorado by completion of the probationary period. If you meet the education and experience requirements please apply with the City & County of Denver, Career Service Authority, 110 - 16th Street, Denver, CO 80202. The City & County of Denver has a residency rule that requires all employees to reside within the boundaries of the City & County of Denver within 90 days of the standard 6 month probationary period completion. The City & County of Denver is an Equal Opportunity/Affirmative Action Employer.

Electrical Engineer - responsible for the company's hardware and software department. Testing and design of power sources. Testing and design of computer circuits. Assembling and testing of personal computers. Testing and design of telecommunication computers. Interfacing personal computers with telecommunication computers. 8:30 am - 5:30 pm. 40 hrs/wk. $33,060 per annum. Require BS in Electrical Engineering and one year's exp in the job offered or one year exp as Laboratory Assistant, Laboratory Manager or Equivalent. Exp to include: research and development in computer architecture, including Cmos Logic, TTL Logic, ECL Logic and design of interface hardware; programming of high speed integrated circuits; design and implementation of digital, telecommunication and power circuits; and design and implementation of high frequency Analog AC, DC converters. Exp may be gained before, during or after degree. Send 2 resumes and cover letters (no calls) to J. Davies, JOB# 00906, Ohio Bureau of Employment Services, PO Box 1618, Columbus, OH 43216.

Computer Software Engineer for communications software development for complex realtime security accounting management systems w/emphasis on applications development in C on UNIX & VAX/VMS platforms, serial communications, networking, and structured analysis & design for transaction processing systems. Work w/ min. supervision to design, develop, code, test & implement simulator software & systems on DOS. Develop system & software specs as well as user documentation. Write program & operation documentation & reports. Participate in Request for Proposal studies. Conduct research on relevant applications of current hardware & software tools. Requires B.S. or foreign equiv in Computer Science or related major & 1 year experience in job offered or in real-time software development capacity. Must have prior practical application of the following knowledge in a real-time environment: C language; VAX/VMS, UNIX & DOS platforms; serial communications; structured analysis & design; TCP/IP network protocols; &, either UNIX IPC, CASE tools, or internals & device drivers. Must be eligible to obtain NV gaming card & passport. Job site: Reno, NV. Yrly salary: $36,600. 40 hr. work week. Successful candidate must prove legal right to work permanently in the U.S. Submit resume & copy of ad to #9428893, Nevada Employment Security Division, 70 W. Taylor St., Reno, NV 89509-1700.

Senior Design Engineer: Design and development of electronic ballast for lighting industry. Project management responsibility for the specific product to be introduced. Includes product, introduction process and conception through transition to manufacturing and designing multistage power supplies for fluorescent and other types of lamp applications. Advanced electronic group research and development of new concepts, more efficient circuits/concepts for electronic ballast. $53,000/yr. Reqs. BS Electrical Engr' & 5 yrs. exp. in job. Send resume & Soc. Security # to the Indiana Department of Workforce Development, 10 N. Senate Ave., Indianapolis, IN 46204-2277, Attn: Mr. Gene Replogle. ID# 3379417

Opto-Mechanical Packaging Engineer to lead development of optoelectronic devices for commercial products. Requires 5+ yrs. commercial experience with semiconductor optoelectronics packaging, design and processing. B.S. or M.S. in mechanical engineering or related field, with expertise in mechanics, micromechanical components, optics and materials. Submit resumes to Human Resources, Dept. 95-PKG, 2330 Faraday Ave., Carlsbad, CA 92008. EOE M/F/D/V

Scientist/Engineer - Solid-State Power Device - Cree Research, Inc. is the world leader in silicon carbide semiconductor device technology. The continued growth of our Research Triangle Park, N.C. facility has created an opening for a Solid-State Power Device Scientist/Engineer to perform silicon carbide device R&D. This position requires experience in the design and fabrication of high voltage, silicon power MOSFETs. An advanced degree and experience with MOS device modeling, device processing and other power device (e.g. thyristor, rectifier, BJT, IGBT) are desired. We offer a competitive salary and excellent benefits package. Please submit resume, including salary requirements, to: Human Resources, Cree Research, Inc., 2810 Meridian Parkway, Suite 176, Durham, NC 27713. EOE/AA Employer

Engineering Opportunity: Aeroquip Corporation is currently seeking an Electrical Engineer for our Corporate Technology Lab located in Ann Arbor, MI. Aeroquip Corporation, a TRINOVA company, is a world leader in the manufacture and distribution of engineered components and systems for industry. The Corporate Technol-

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ogy Lab is the center of innovation for the company's New Business Development Organization. Only about a year old, the Lab provides self-starters who are able to balance a variety of simultaneous projects, a unique opportunity to become involved in the development of a dynamic new enterprise. Qualifications for this position include: Advanced degree; Experience in sensors, communication, instrumentation, fiber optics, and circuit design; Experience in electronic product design and lithography preferred; A minimum of 2 years' experience in the electronics industry. To be considered, please send your resume and salary history/requirements to: Aeroquip Corporation, Corporate Technology Lab, Dept. A, 2323 Green Rd., Ann Arbor, MI 48105-1530. All replies will be held in confidence. We are an equal opportunity employer.

Electrical Engineer: A NW OH engineering firm has an opening for an Electrical Engineer to prepare detailed plans and specifications for electrical power distribution systems for hazardous areas. Duties include short circuit and overcurrent protection and calculations, indoor/outdoor illumination for commercial and industrial applications, cost estimates, detailed electrical equipment specifications, National Electrical Code (NEC) and American Disability Act (ADA) compliance reviews, standby emergency equipment and generators, energy management, motor controls, schematic diagrams for control applications, and lightning protection. Must have 3 yrs experience in designing power distribution systems for all the following hazardous locations: 1) wastewater treatment plants; 2) leachate and sewage pumping and storage facilities; 3) solid waste landfills. Education (BSEE) must include one course in each one of the following topics: power systems, logic and switch theory and instrumentation and control design. EOE. 40 hrs/wk - 8am-5pm, Mon-Fri; Salary - $3,120/month. Send 2 resumes & cover letters (no calls) to: J. Davies, Job #00853, Employment Services, P.O. Box 1618, Columbus, OH 43216.

Newly formed company in Atlanta, GA providing proprietary testing services to fabricators and assemblers in the electronic packaging industry requires a Manager having 5+ years experience in electronics manufacturing industry. Must have: successful sales & manufacturing involvement, versatility, significant contacts. Reply in confidence to IEEE Spectrum, Box 3-1, 345 E. 47th St., New York, NY 10017.

Director of Engineering: We are a leading manufacturer of frequency control devices with a worldwide reputation and marketing for quality and design, which has an immediate requirement for a highly motivated engineer. Qualified candidates should have 10+ years related experience, preferably in both the crystal and oscillator areas along with an EE degree. Prior managerial experience a plus. Competitive salary and excellent benefit package commensurate with this high profile position; reporting to the President. Excellent family oriented northeastern location with a climate offering something for every kind of outdoor enthusiast. Submit detailed resume of educational background, work and salary history, and references to: Bliley Electric Company, Attn: Richard D. Bliley, President, P.O. Box 3428, Erie, PA 16508. EOE M/F

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coming in spectrum

Digital TV—some inside stories

This extensive *IEEE Spectrum* report brings together the people who have been hammering out a proposed U.S. standard for digital high-definition television (HDTV). Their first-hand accounts explain why that standard is being laid out the way it is. The companies involved include Philips Laboratories, Thomson Consumer Electronics, AT&T Bell Laboratories, General Instruments, and the David Sarnoff Research Center.

Other sections of the report will dissect interactive TV from the standpoint of the network and investigate design issues surrounding video servers and set-top boxes. Also discussed will be two standards, one for videotape in digital video recording, and the other for digital satellite TV, which was recently introduced in the United States.

Rounding out the world picture will be overviews of the status of advanced TV efforts in Europe and Japan.

Also, this issue will see the first of a new series entitled "Spectrum Visits." The first trip will be to see how technology proposed for HDTV is put through its paces at the U.S. advanced TV committee's testing laboratory.

Focus Report: PCs and workstations

In its fifth annual report on engineering workstations and PCs, *Spectrum* breaks with the survey approach of the past and instead delves into the most important new aspects of desktop computing.

Readers will get a first look at one of the most significant developments in the technology of reduced–instruction-set computing (RISC): the hardware reference platform for the PowerPC, which is being jointly developed by Apple Computer, IBM , and Motorola.

A related story describes how one of the latest compilers was created in parallel with the design of the high-speed RISC chip it was destined to support. The intent was for the hardware and software engineering teams to optimize their wares to their own and each other's maximum advantage.

Wanted: EEs with children

Are you ecstatic over the way your kid decided to become an engineer after visiting your local science or technology museum? Or are you perhaps exasperated by the inaccuracy or boring nature of the EE-related exhibits?

Here's your chance to say what you —and the younger generation— think and why!

IEEE Spectrum is seeking engineers and their children willing to evaluate the quality and enjoyability of EE-related exhibits in major science and technology museums around the world. A summary of the evaluations of U.S. museums is scheduled to appear in the September 1995 *Spectrum* as the first of an occasional series on technology-related travel. Evaluations of museums in other nations will appear in later issues.

This project should (we hope) be fun as well as informative for both you and one or more local "test children"—be they your relations or a neighborhood buddy.

Intrigued? To receive further information on how to participate, please send your name, home address, telephone number, e-mail address, and names and ages of volunteer test children by **mail** to Trudy E. Bell, Senior Editor, *IEEE Spectrum*, 345 E. 47th St., New York, NY 10017, U.S.A.; by **fax** to 212-705-7453 or by **e-mail** to t.bell@ieee.org.

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